

Market Design and Gaming in Competitive Electricity Markets

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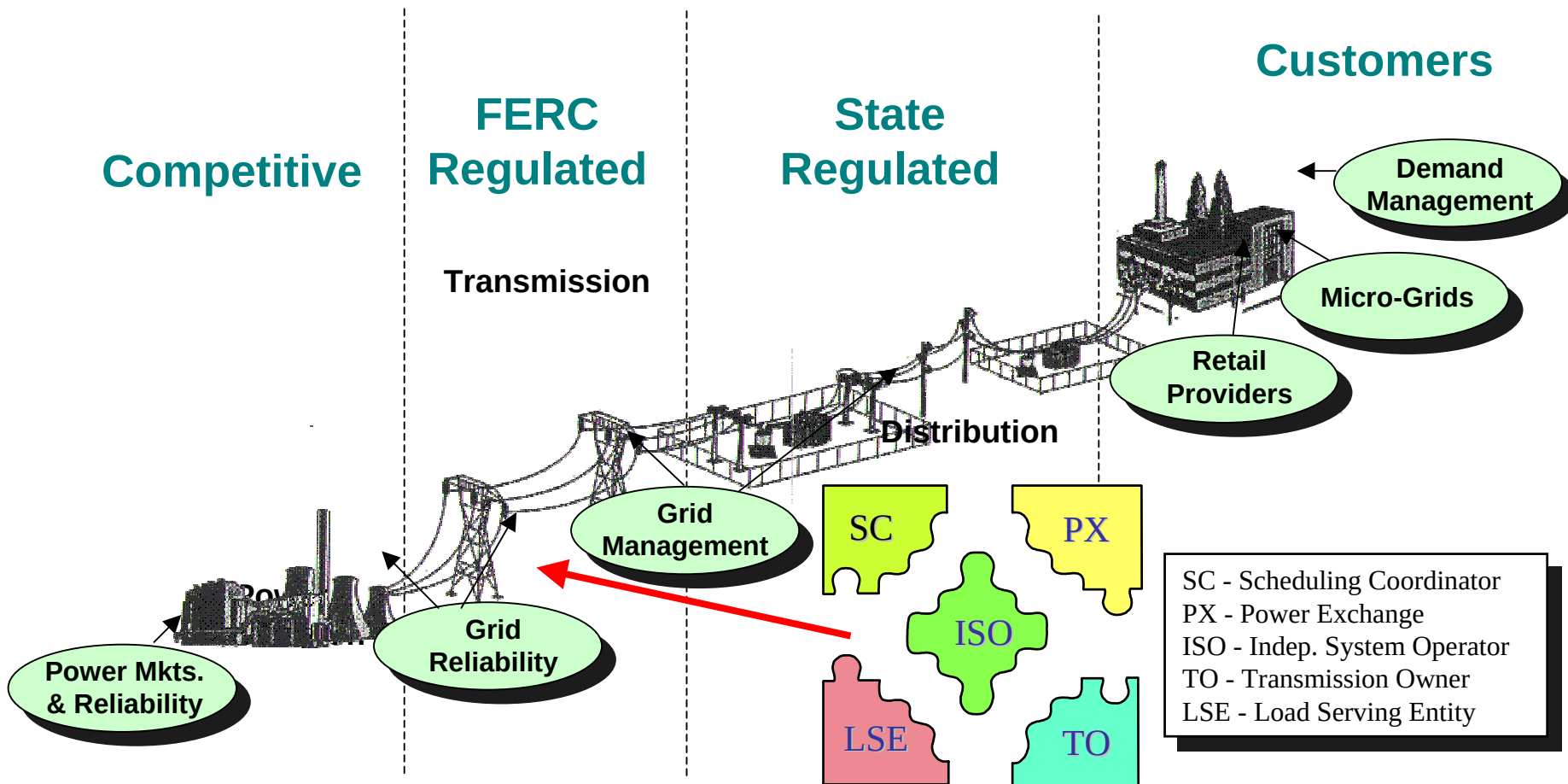
OBJECTIVE OF MARKET DESIGN

Develop a set of trading rules and procedures so that when all market participants act selfishly so as to maximize profit while following the rules, the market outcome will replicate the results of a benevolent central planner with perfect information, or a perfectly regulated monopoly



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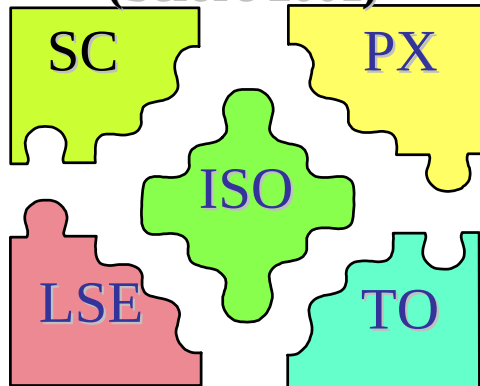
POWER INDUSTRY RESTRUCTURING



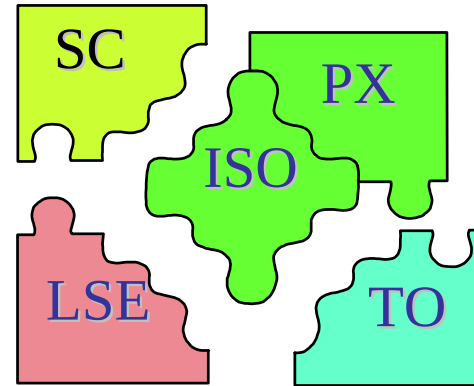


Alternative Market Structures

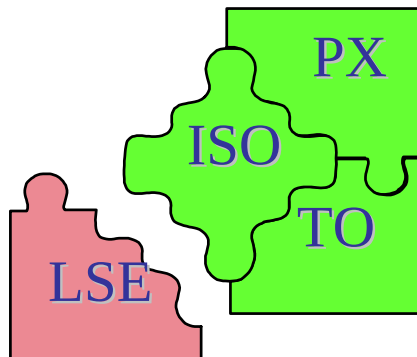
CALIFORNIA (before 2001)



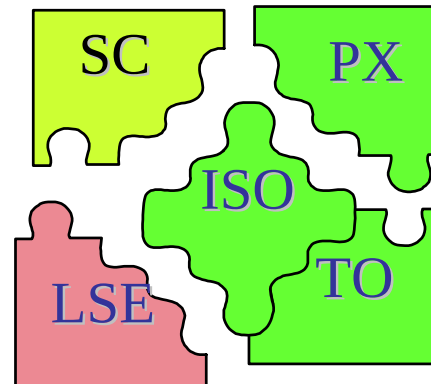
PJM



U. K. (before 2001)



NORD POOL

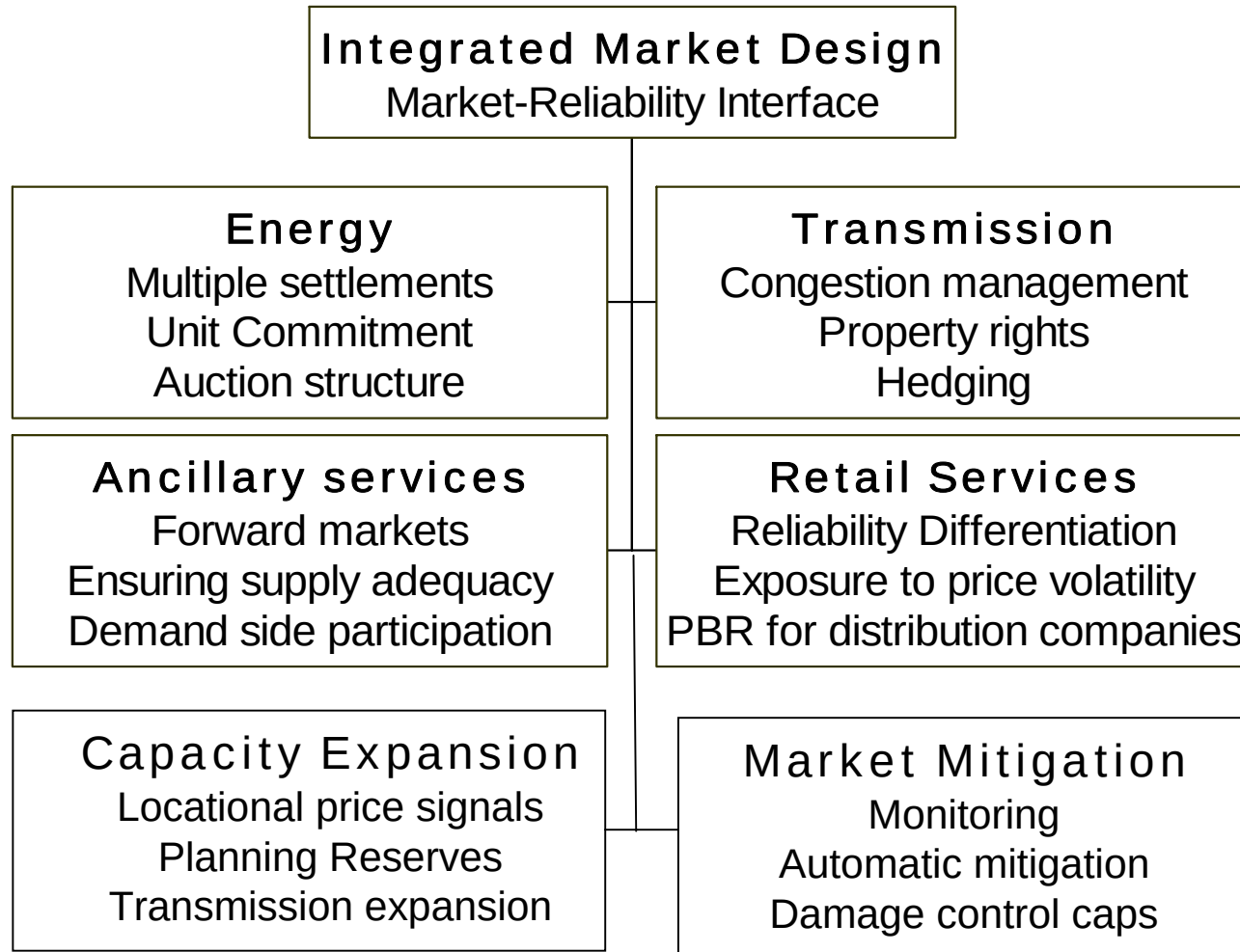


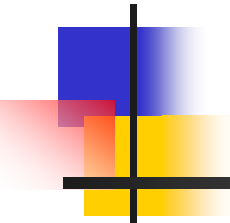
The Basic Tradeoffs

- A decentralized electricity market is inherently incomplete. The set of products traded does not capture all the complexities of the system (e.g. ramp rate and reactive power are not priced). Results in suboptimal dispatch and uplifting of non-priced coordination costs, which are susceptible to gaming.
- A centralized market must use multidimensional bidding schemes (e.g. energy, start up costs, ramp rate, inflexibility etc.) and complex market clearing rules. Susceptible to incentive compatibility problems (bidders can game the market by revealing false information).



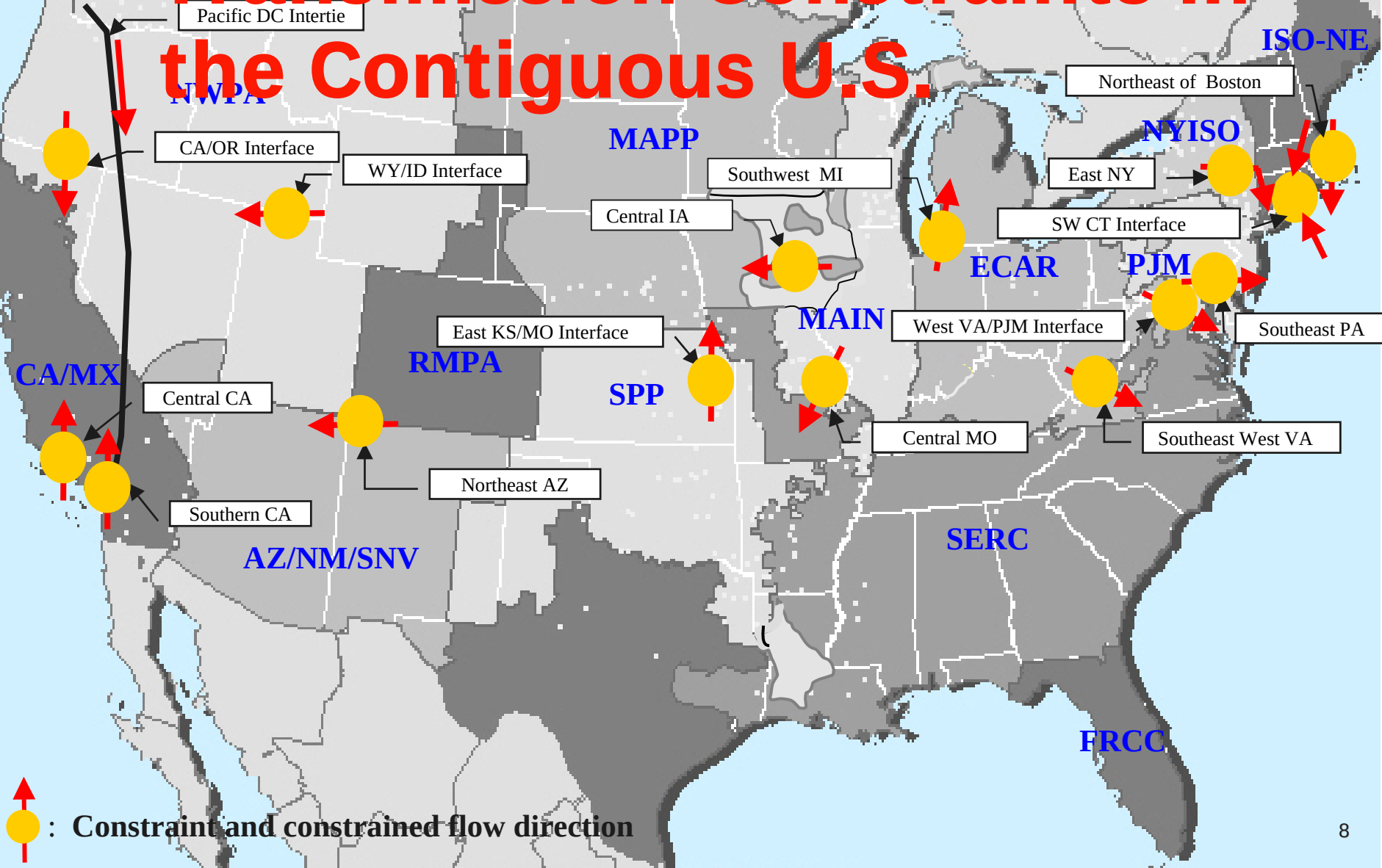
Market Design Components





CONGESTION MANAGEMENT

Transmission Constraints in the Contiguous U.S.

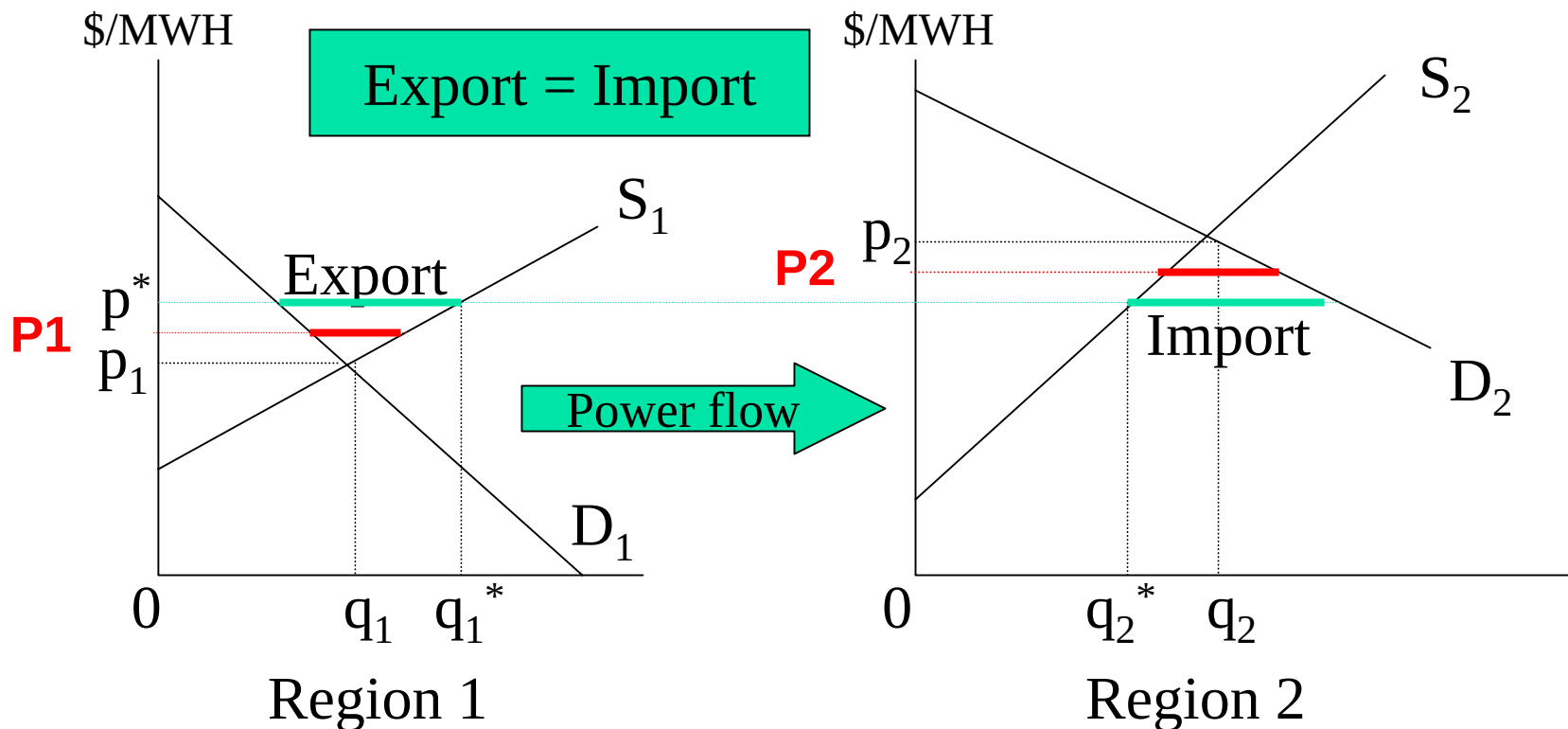




Objectives of Congestion Pricing

- Provide incentives to generators to account for transmission constraints in their schedules by direct assignment of congestion cost.
- Provide price signals for efficient redispatch due to transmission constraints
- Create price signals for efficient use of the transmission system
- Create price signals for transmission upgrades
- Prevent gaming due to misallocation of constraints cost

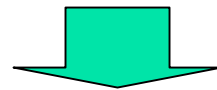
Locational Marginal Prices



With transmission constraint

General Definition of LMP

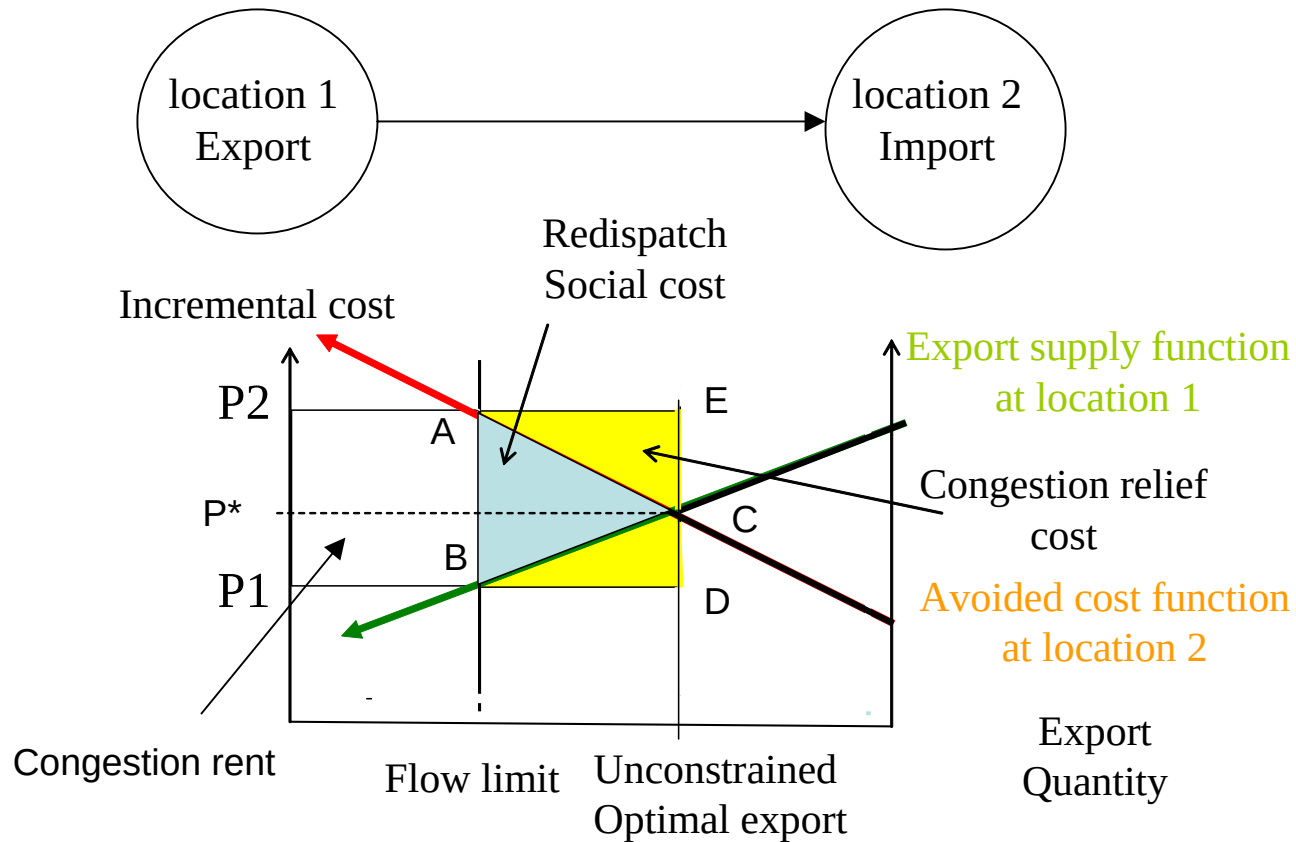
The LMP is the cheapest cost of delivering one additional MWh to a location while respecting all limits (including contingency limits)



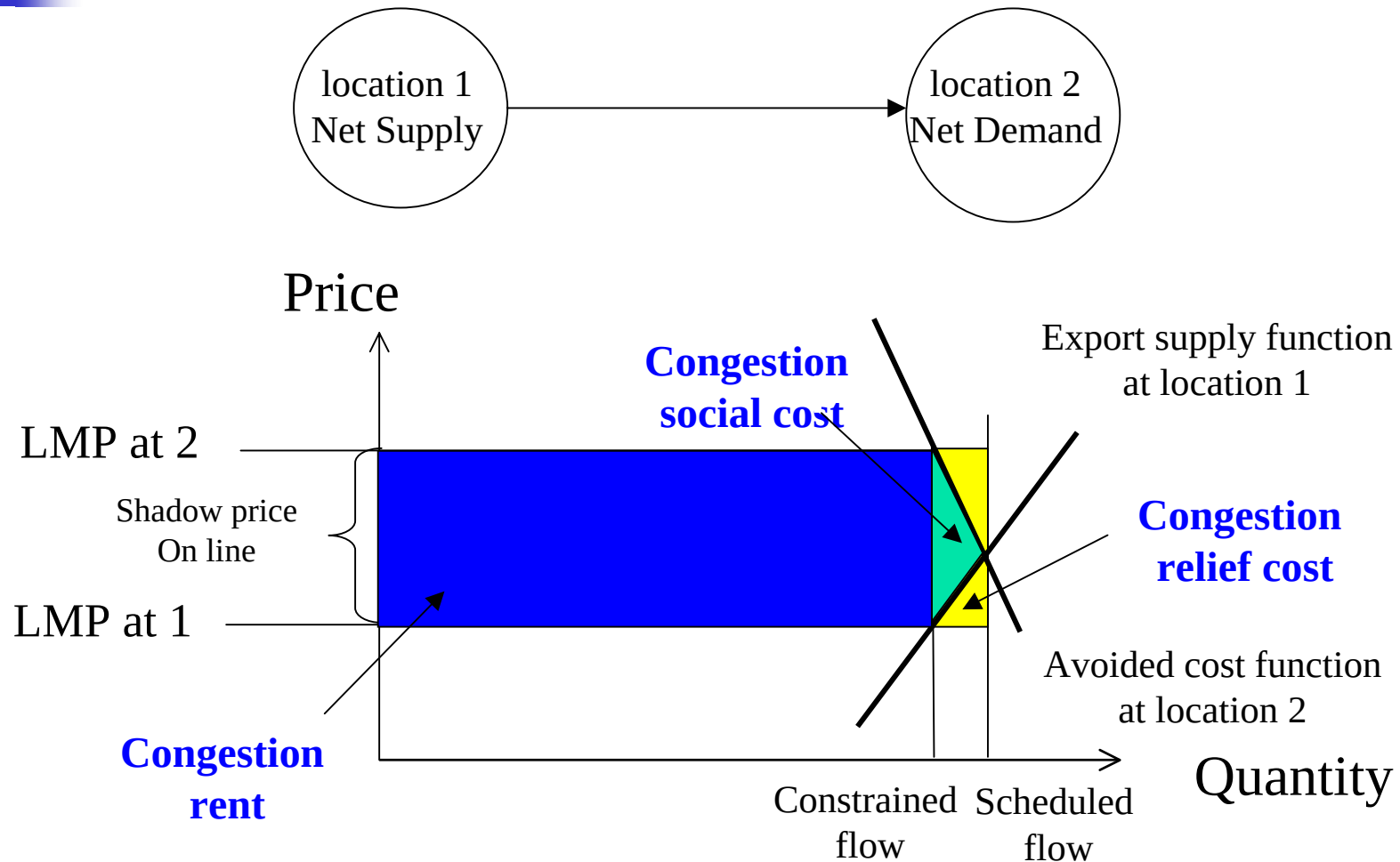
Marginal value of transmission between two locations = LMP difference



Alternative Measures of Congestion Cost and Corresponding Settlements



The case for socialization of congestion relief cost





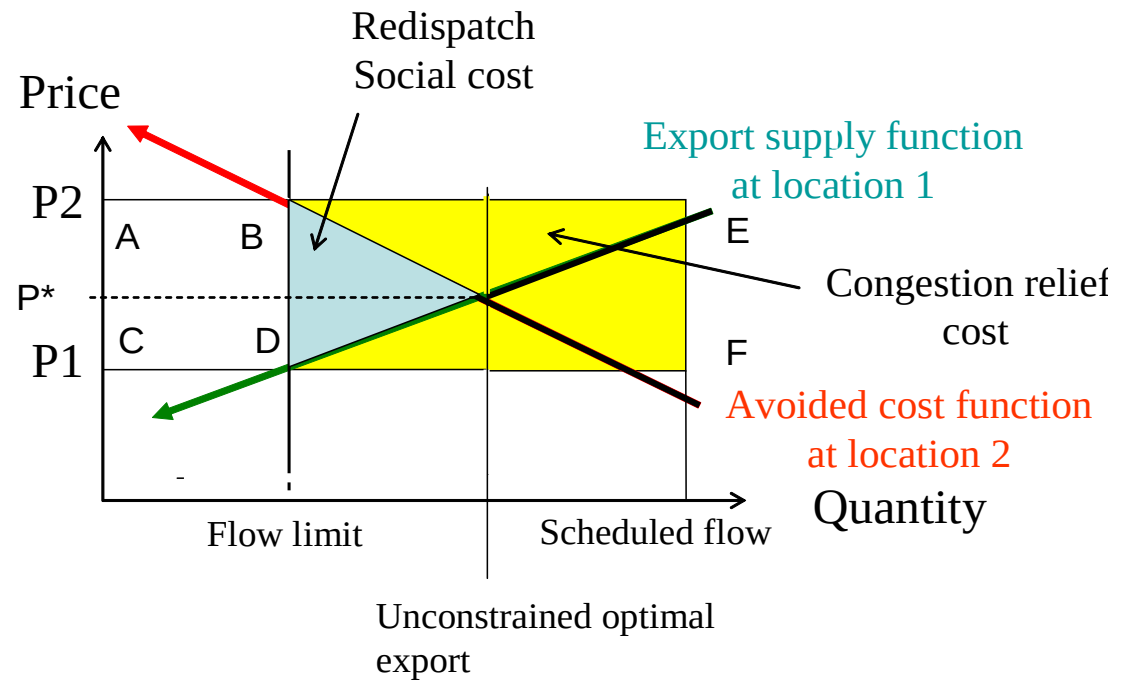
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The DEC Game





ENRON's "Death Star" strategy

Power play

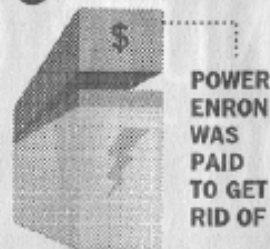
After California deregulated its energy market, Enron figured out a number of ways to manipulate it. Here is how one of them, code-named "Death Star" by Enron's energy traders, worked, according to memos released by federal investigators:

1

A state agency known as the Independent System Operator was responsible for ensuring that California's residents had power when they needed it. Energy providers would schedule deliveries to meet the needs.

2**ENRON'S SHARE**

Enron, which supplied a share of this power, would intentionally overschedule the amount it knew the system could handle.

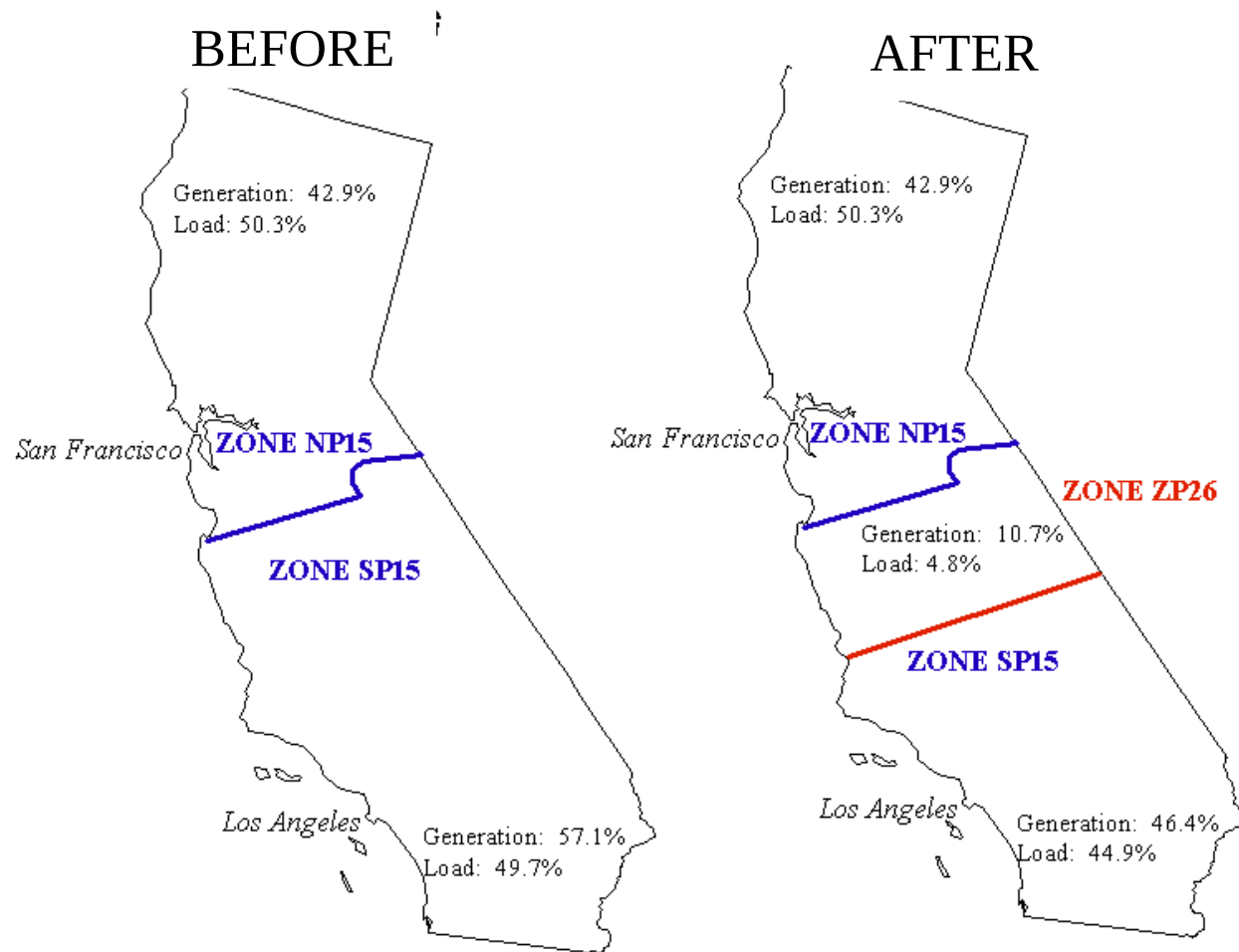
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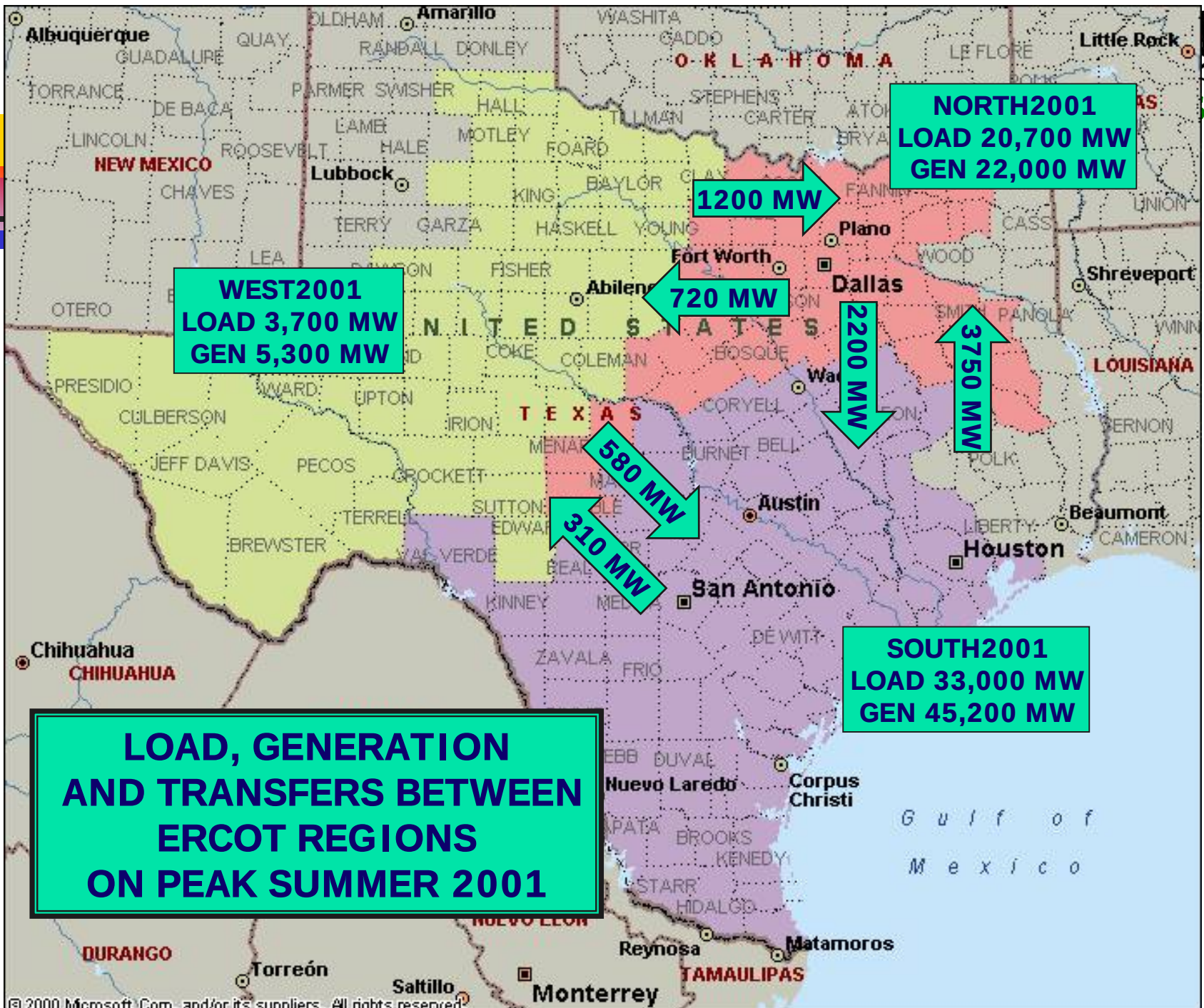
The state agency, unable to monitor the actual usage and believing that the power grid would be overloaded, then paid Enron to deliver the "excess" electricity somewhere else to avoid congestion. Often that was out of state where it was even harder to track.

4

Enron, realizing that it could repeat this pattern, often never had to buy the power that it promised to sell to the agency, increasing its profits even more.

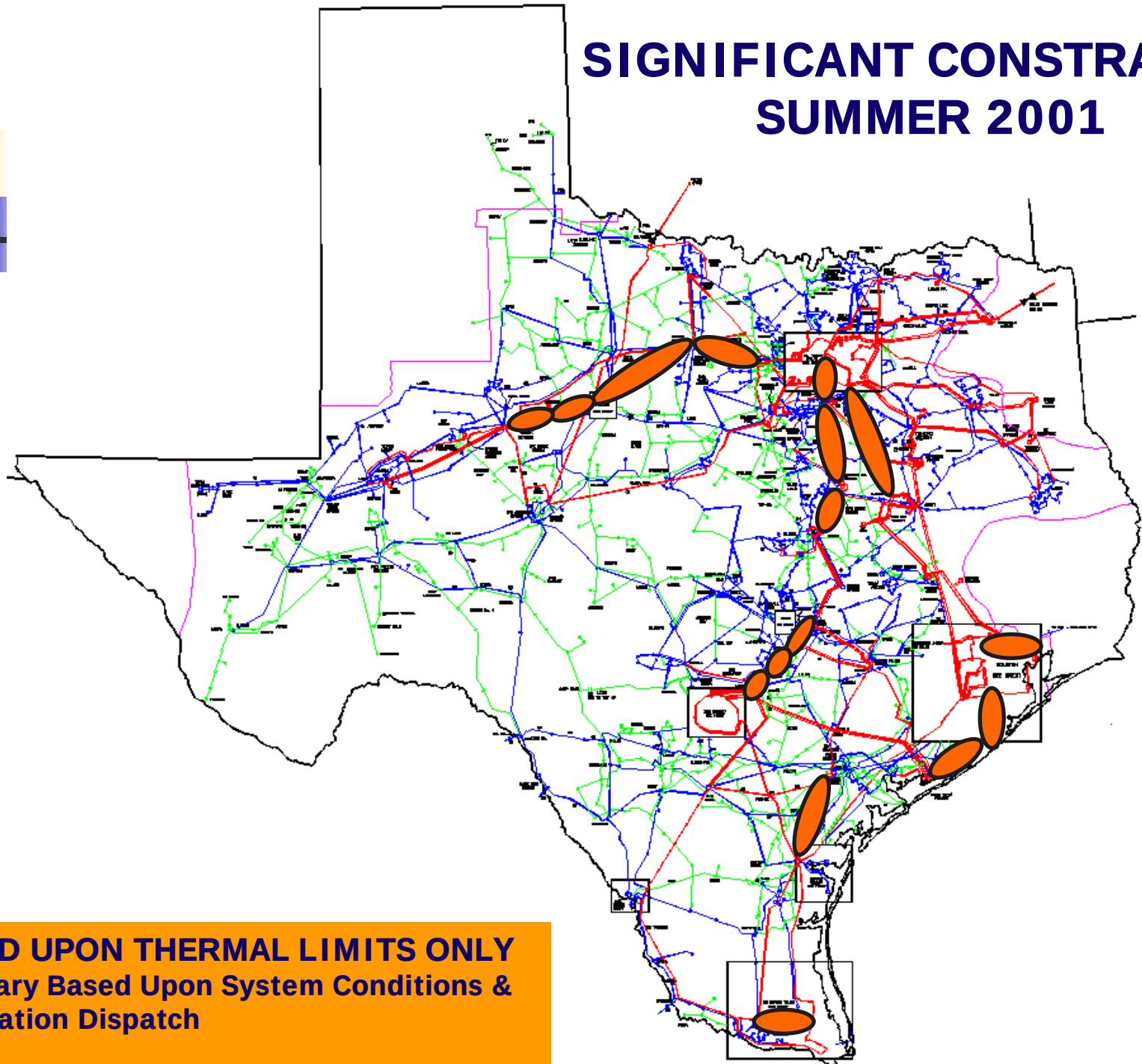
The DEC Game on Path 26 in California





**LOAD, GENERATION
AND TRANSFERS BETWEEN
ERCOT REGIONS
ON PEAK SUMMER 2001**

SIGNIFICANT CONSTRAINTS SUMMER 2001



BASED UPON THERMAL LIMITS ONLY
Will Vary Based Upon System Conditions &
Generation Dispatch

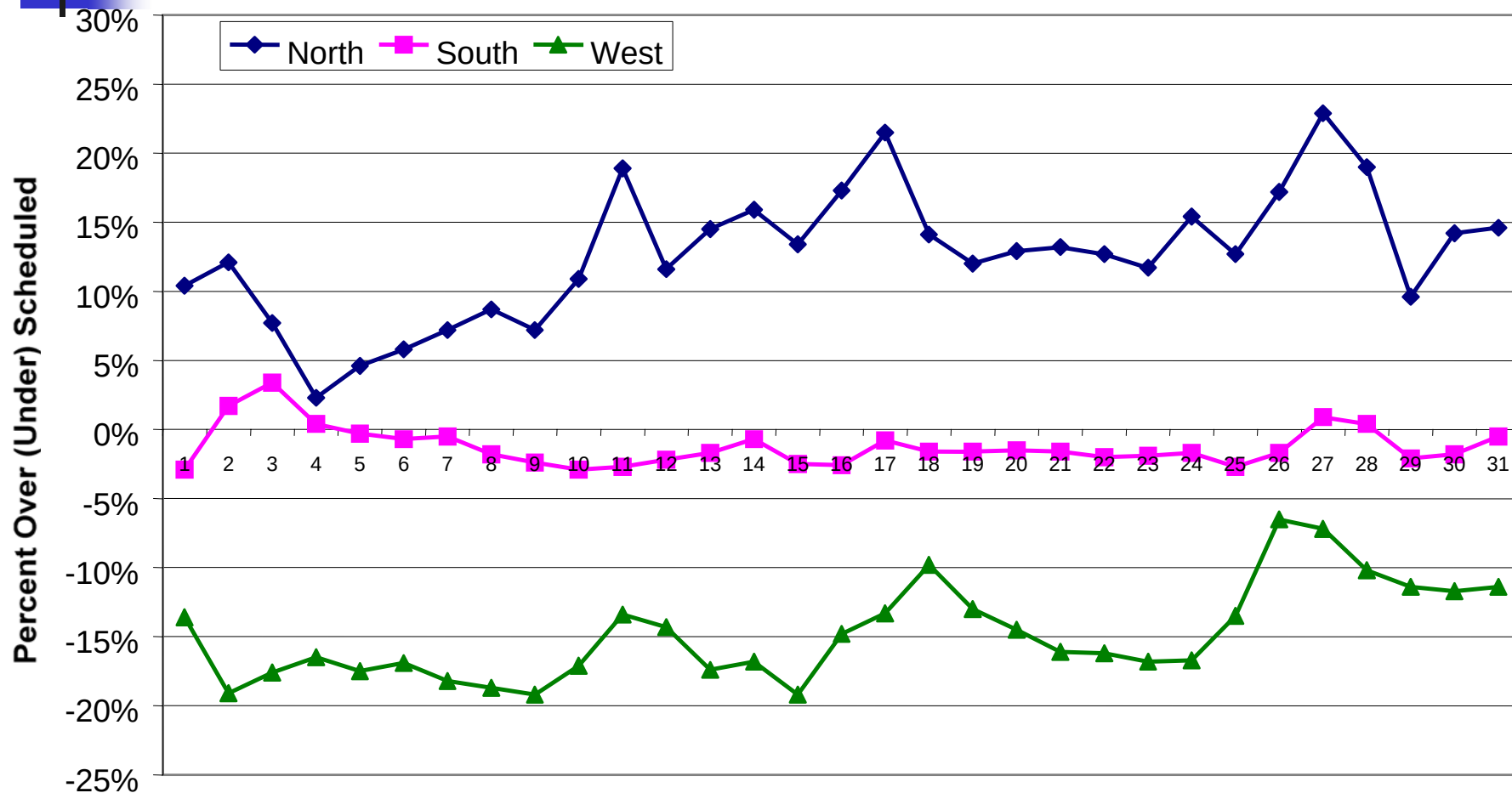
ERCOT Initial Design

- Zonal markets linked by CSCs (4 zones 4 CSCs)
- QSEs submit balanced bilateral zonal schedules and zonal portfolio balancing energy offers with resource specific premiums
- All schedules accepted. Congestion relieved in two steps
 - **Interzonal (CSC) congestion relieved with counterflow from zonal balancing energy offer stack (INCs and DEC).**
 - **Intrazonal (OC) congestion relieved (if possible) by dispatching local balancing energy resources (redispatched resources paid market clearing premiums if competitive solution exists, otherwise they get OOME payments**
- **Counterflow cost initially socialized with two “trigger points”**
 - **CSC congestion charges and TCRs to be activated 6 months after cumulative counter flow cost reaches \$20M over 12 month.**
 - **Direct assignment of OC congestion cost to be initiated 6 months after cost reaches \$20M over 12 month period.**

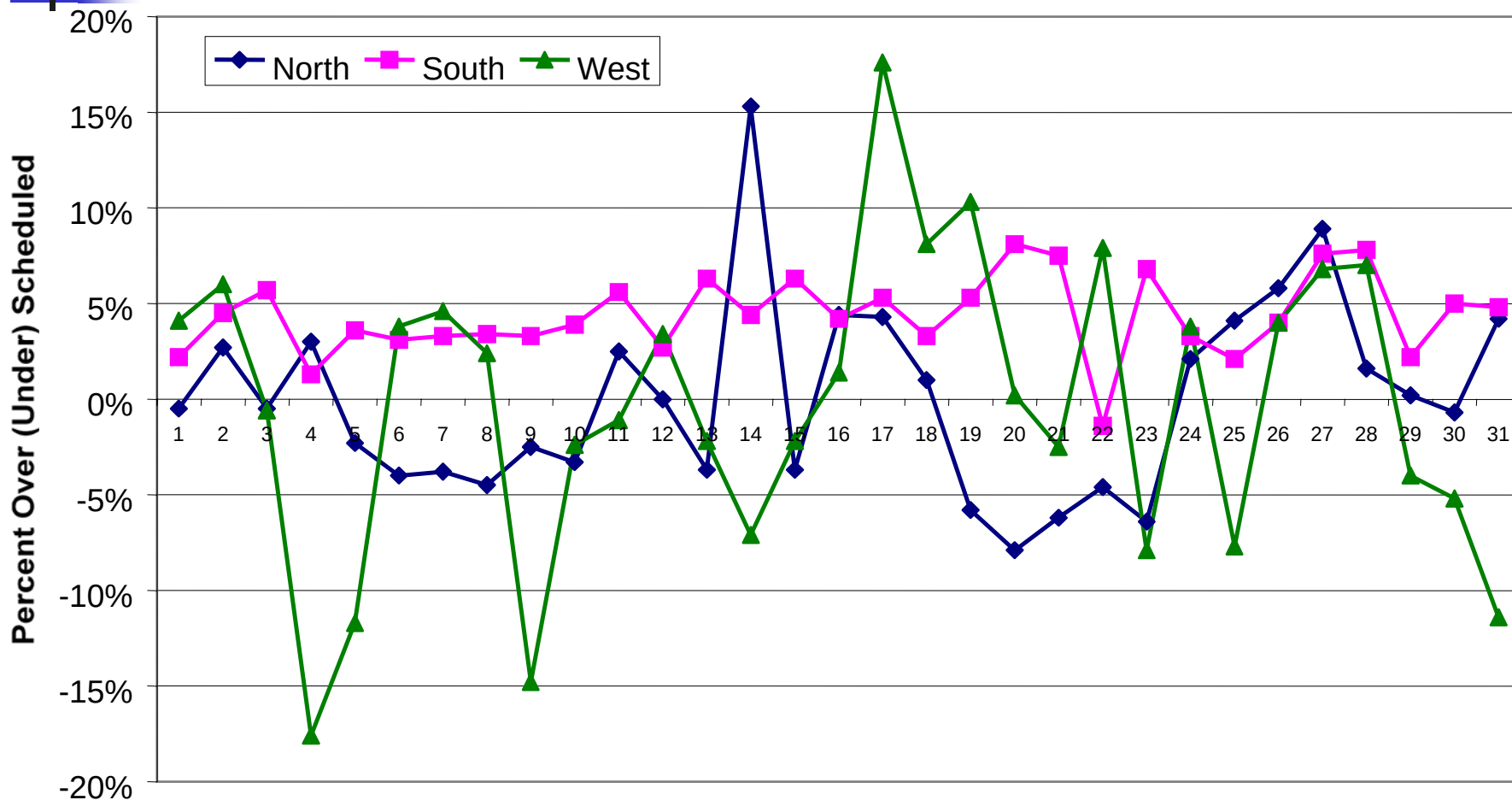
Observed Scheduling Patterns at ERCOT During Aug. 2001

- Consistent overscheduling of generation in the South Zone which resulted in significant resource imbalance credits to QSEs from ERCOT.
- Consistent overscheduling of load in the North Zone which resulted in significant load imbalance credits to QSEs from ERCOT.

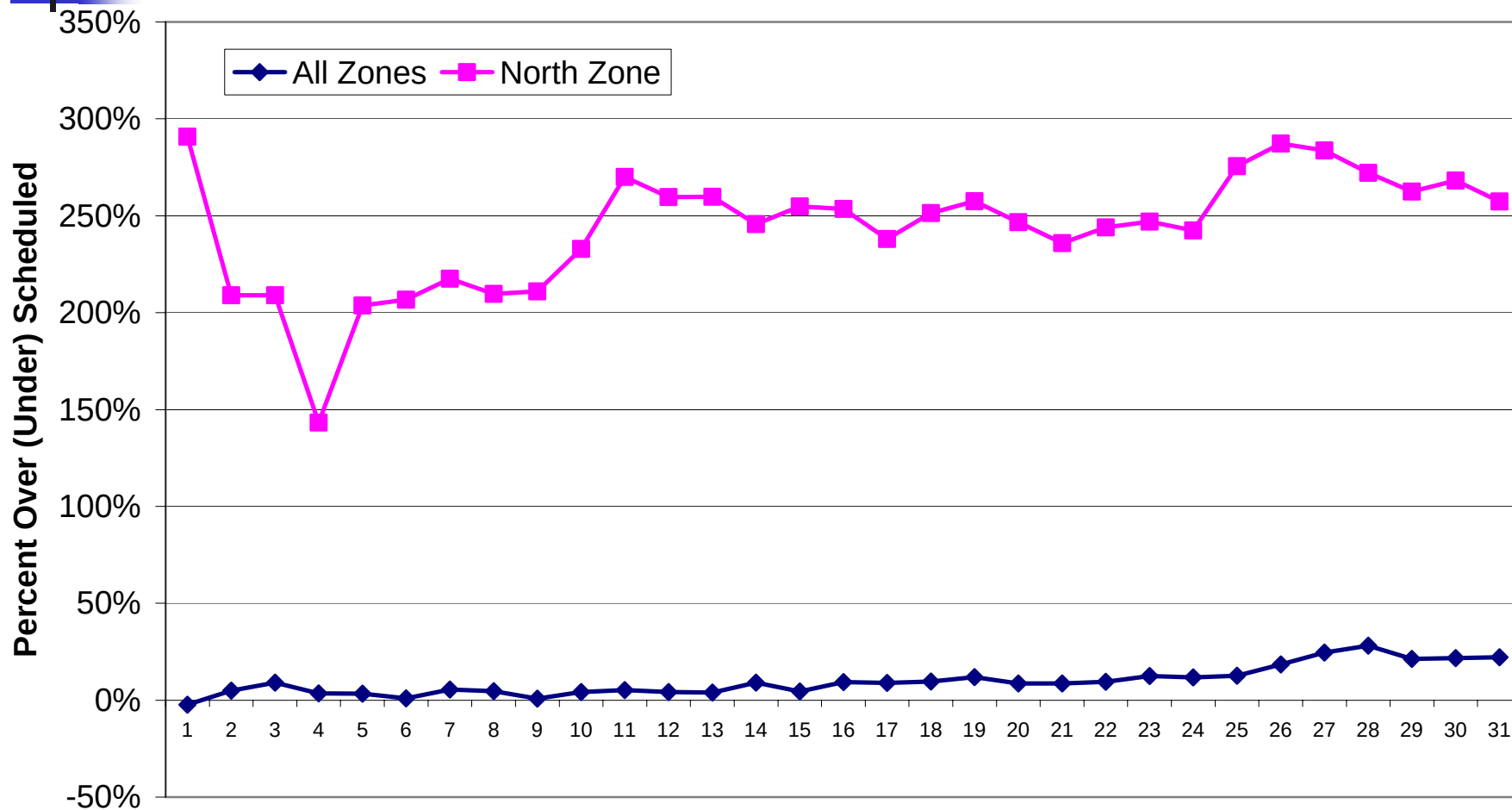
ERCOT Daily Load Imbalance by Zone, August 2001



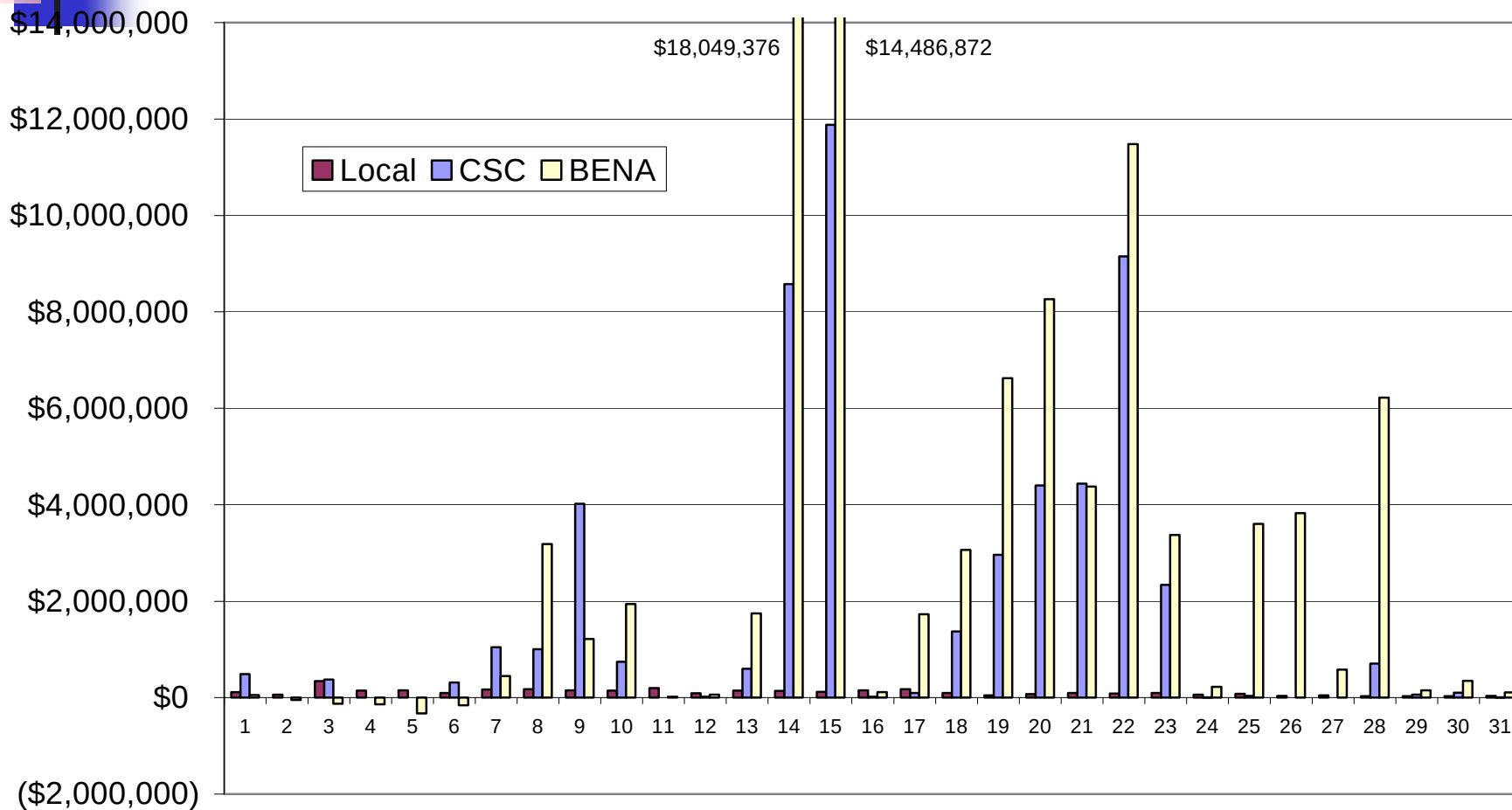
ERCOT Daily Resource Imbalance by Zone, August 2001



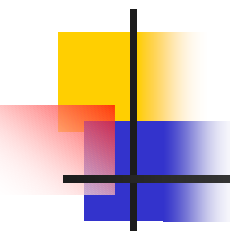
QSE B Daily Load Imbalance, August 2001



Daily Costs for Local Congestion, CSC Congestion, and Total BENA

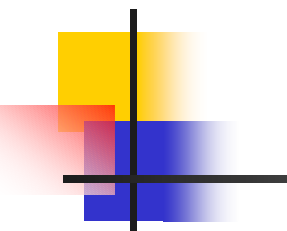


August 2001

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Findings

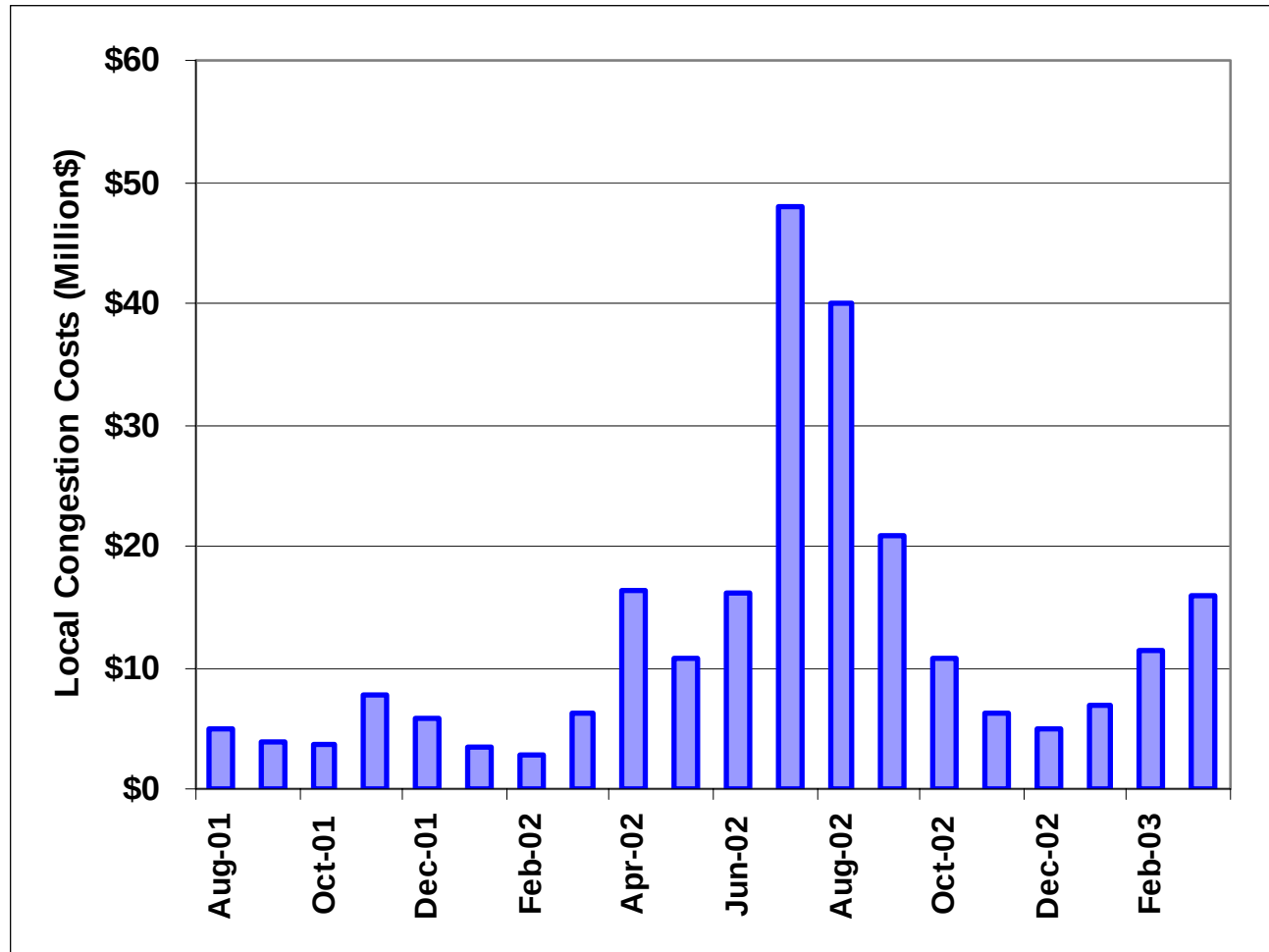
- Six QSEs received more than \$46 million in LI credits for the 15 day period.
 - August 14 and 15 accounted for 44% of LI credits to the six QSEs.
 - Three of the six QSEs received 91% of LI credits for the 15 day period.
- Eight QSEs received \$48 million in RI credits for the 15 day period.
 - August 14 and 15 accounted for 38% of RI credits to the eight QSEs.
 - Three of eight QSEs received 95% of RI credits for the 15 day period.



Epilog

- Interzonal Congestion charges were activated in February 2002
- Interzonal congestion uplift was virtually eliminated and the DEC game between zones was suppressed.
- The PUCT filed suite against the QSEs that collected BENA settlements through over and under scheduling (for protocol violation). An out of Court settlement was reached with several of the QSEs (not including ENRON) who agreed to refund a total of about \$25 million dollars. The settlement is pending commission approval.
- Local congestion cost is still socialized and uplift cost is escalating
- New rule will institute a “Texas Nodal” system including direct assignment of all congestion rents by 2006

Uplifted Local Congestion Cost in ERCOT

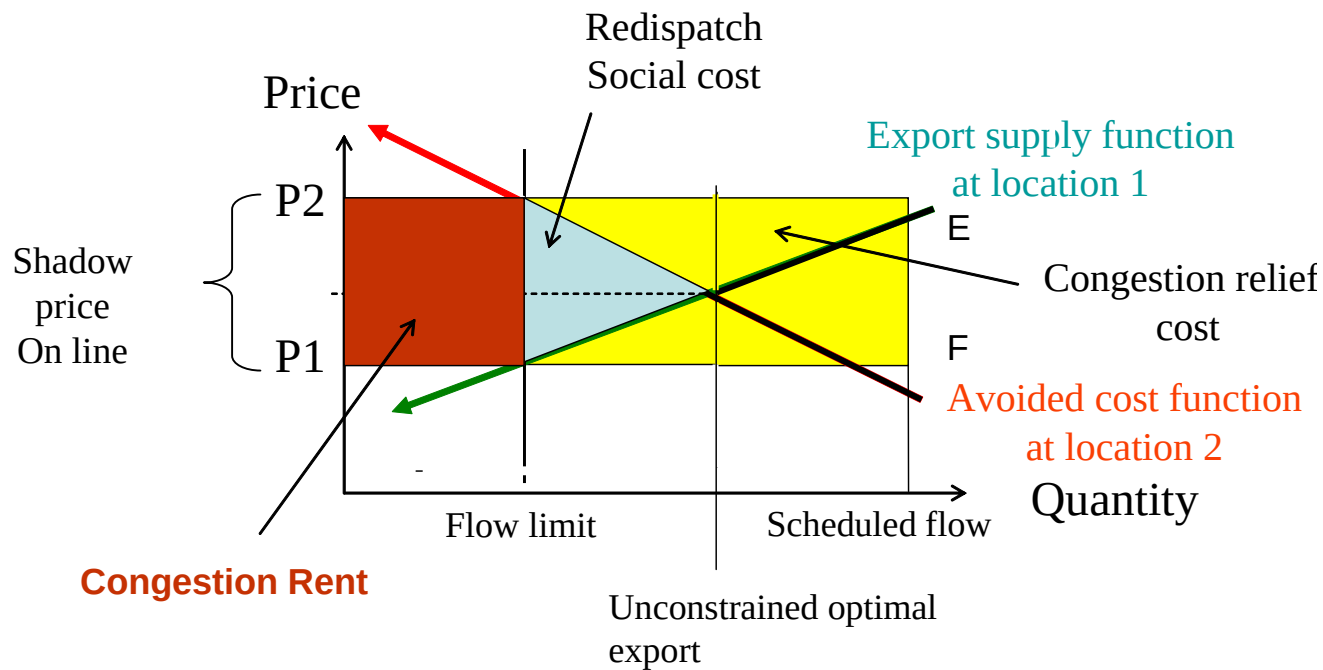


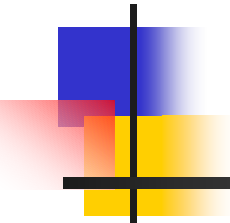


Pricing Congestion the Right Way

- Charge scheduled transactions the locational price differences between injection and withdrawal point OR
- Charge scheduled transactions a congestion fee that equals to their induced flow on congested lines times the “shadow prices” on these lines
- Pay redispatched INCs at import location P2 and sell back energy to DEC at export location P1

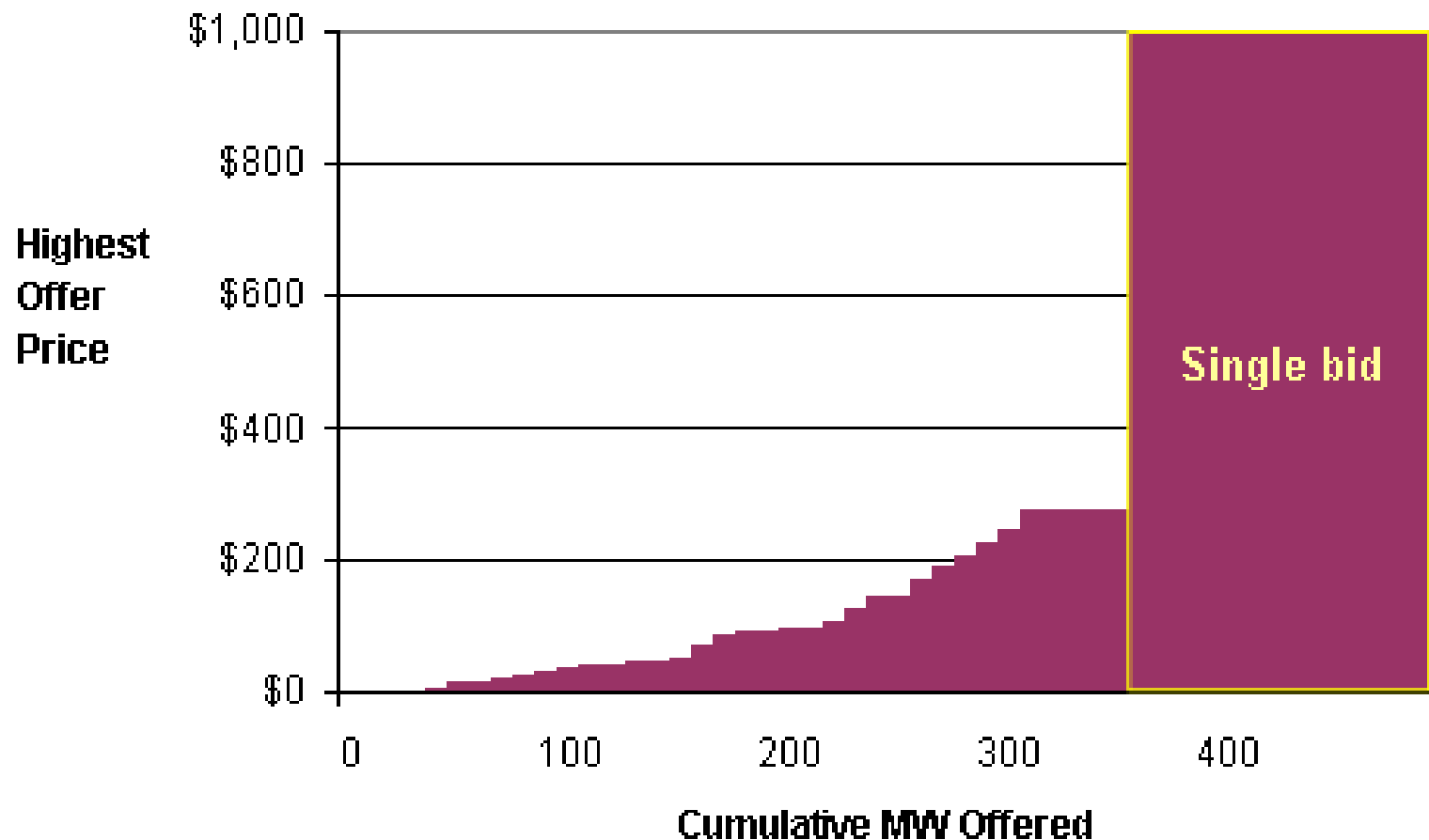
Congestion Rent is the Only Incentive Compatible Congestion Charge



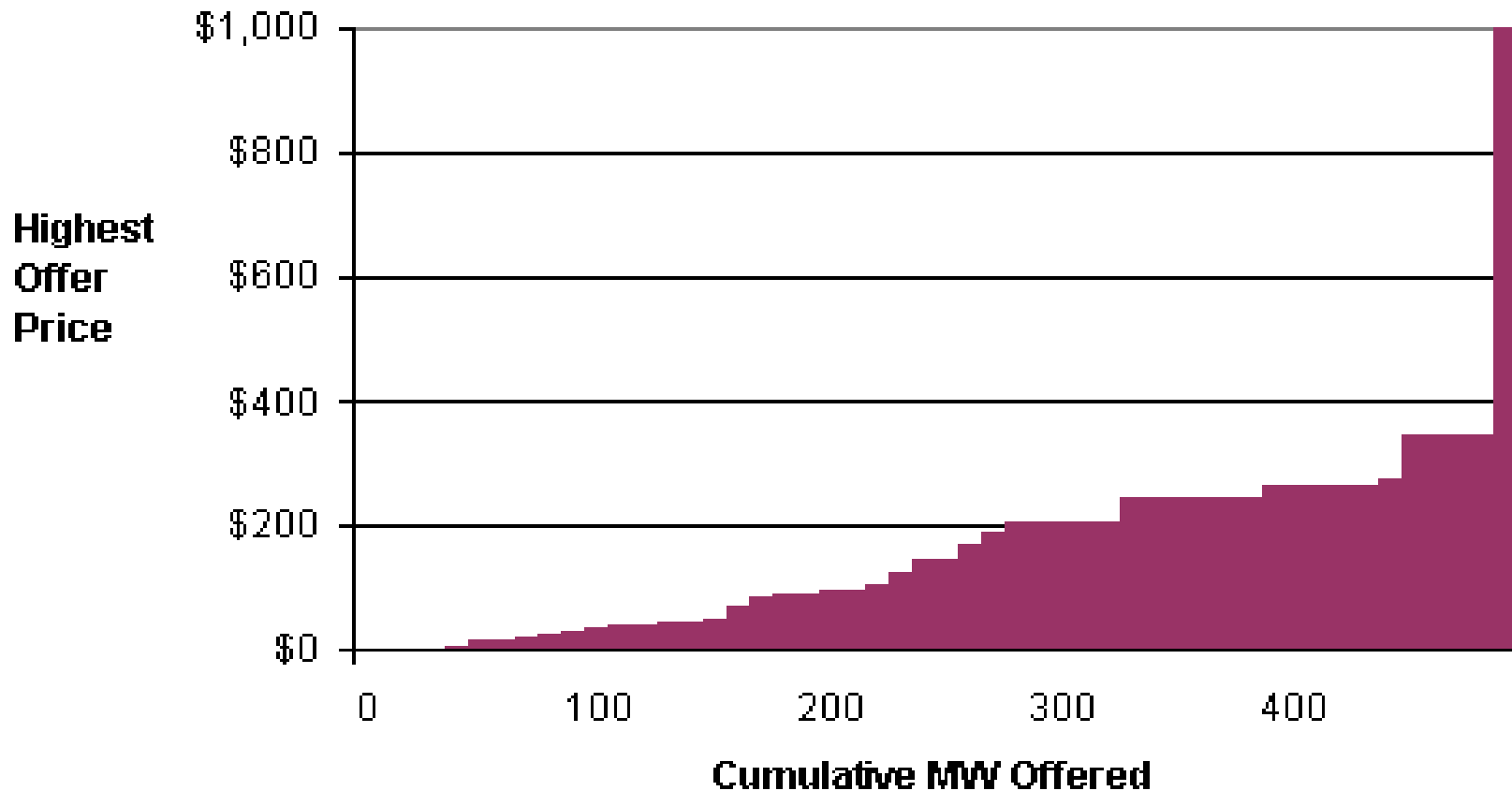


ENERGY MARKETS

Economic Withholding by Pivotal Supplier



“Hockey Stick” Bidding in RT Ballanacing Market

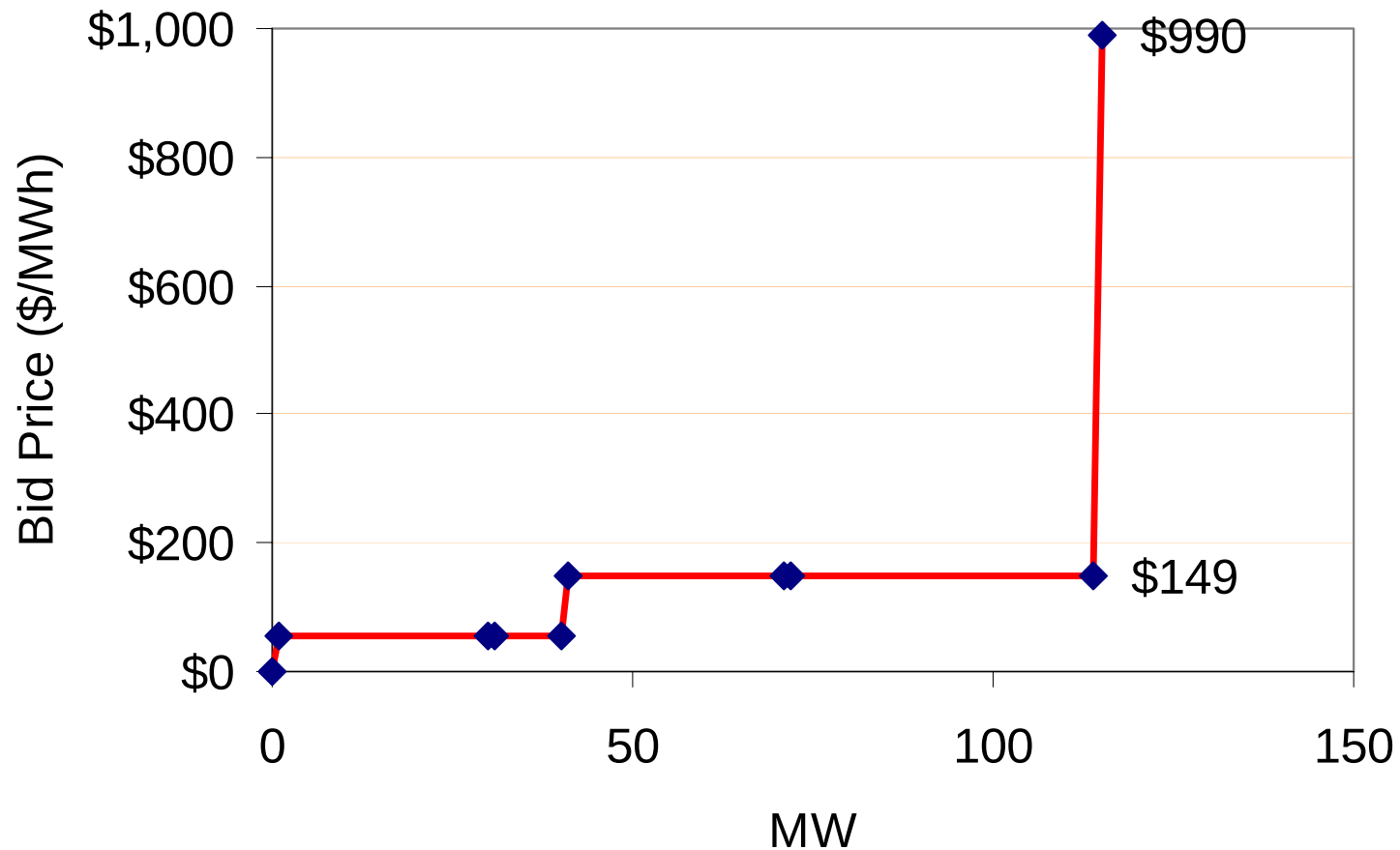


The Texas Ice Storm

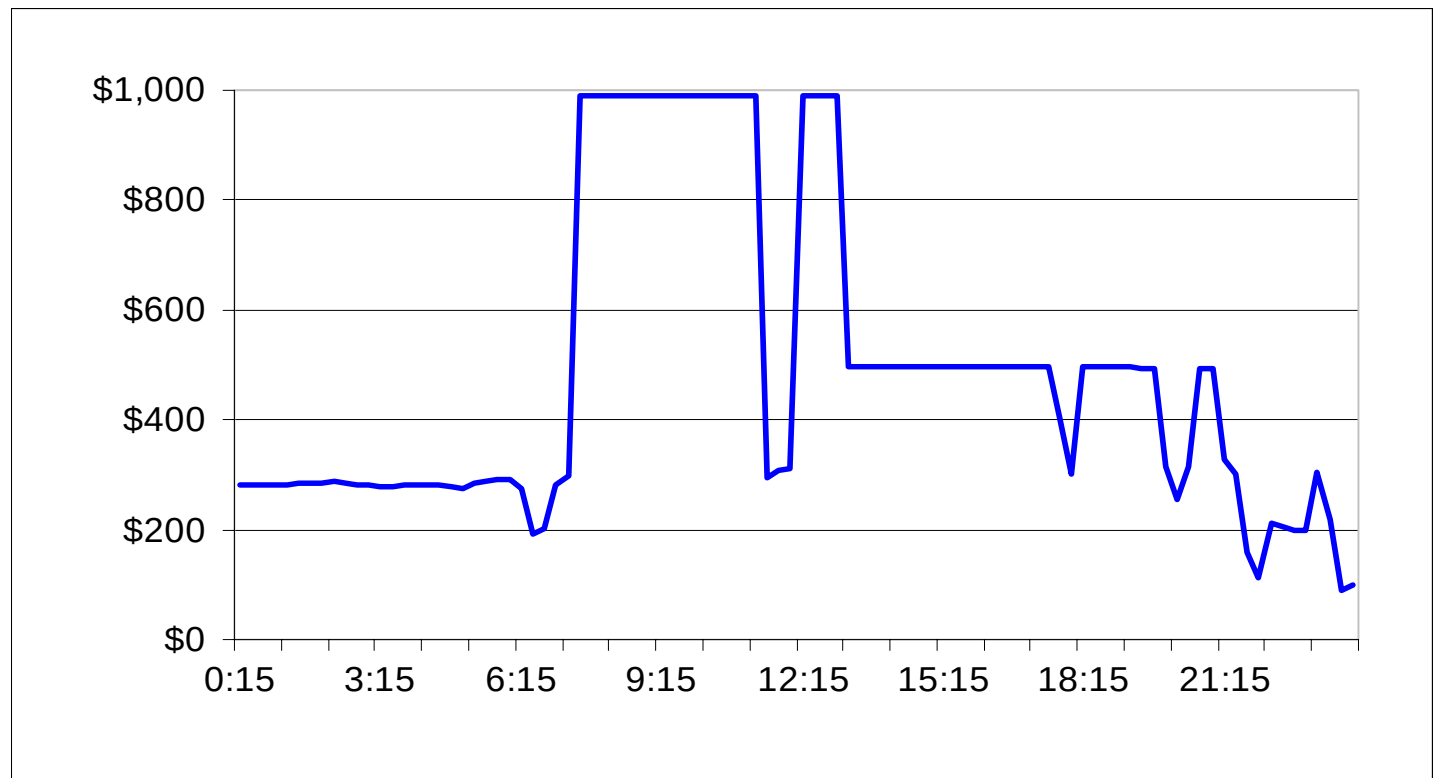
2/25-27/2003

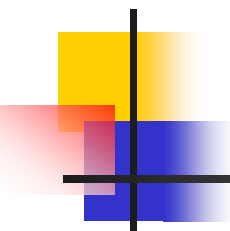
- ERCOT had to procure 100% of the balancing offer stack during several hours
- Market clearing price was set by 1MW offered on a regular basis at \$990 by a QSE that offered the rest of its balancing energy at \$200/MW or less.
- \$17 million changed hands in few hours
- One REP declared bankruptcy.

Price-Setting Bid Curve at ERCOT, 2/25/2003



ERCOT MCPE by Interval, 2/25/2003



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Why Mitigate

- Market power cannot be eliminated completely. Because of the nature of electricity some suppliers will have locational market power at some times
- New entry takes time and while it happens suppliers can extract unacceptable rents
- Demand inelasticity can result in occasional market failure (markets do not clear or suppliers can name any price they want)
- ISOs are bound by strict rules in acquiring balancing energy and ancillary services that do not allow them to respond to price
- Demand inelasticity and ISO rigidity enables predatory bidding strategies that are designed to exploit market failure conditions

Alternative Approaches to Automatic Market Mitigation

- Damage control offer caps
- Exclusion from price setting
- Out of merit (OOM) dispatch and RMR dispatch
- Must offer requirements
- Mitigation of offers based on conduct and impact test of individual bidders (NYISO)
- Mitigation based on market failure tests (bid sufficiency, pivotal bidder, hockey stick) (ERCOT)

Hockey Stick Mitigation in Texas

(Adopted by the PUCT May 2003)



- If balancing bid stack is exhausted, set clearing price based on 95% of offer stack
- Mitigated MCPE = 95% price point X 1.5
- Offers at prices above mitigated MCPE paid as bid
- Sunshine policy: disclose identity of offerers above \$300/MWh (“Sunshine is the best disinfectant”)

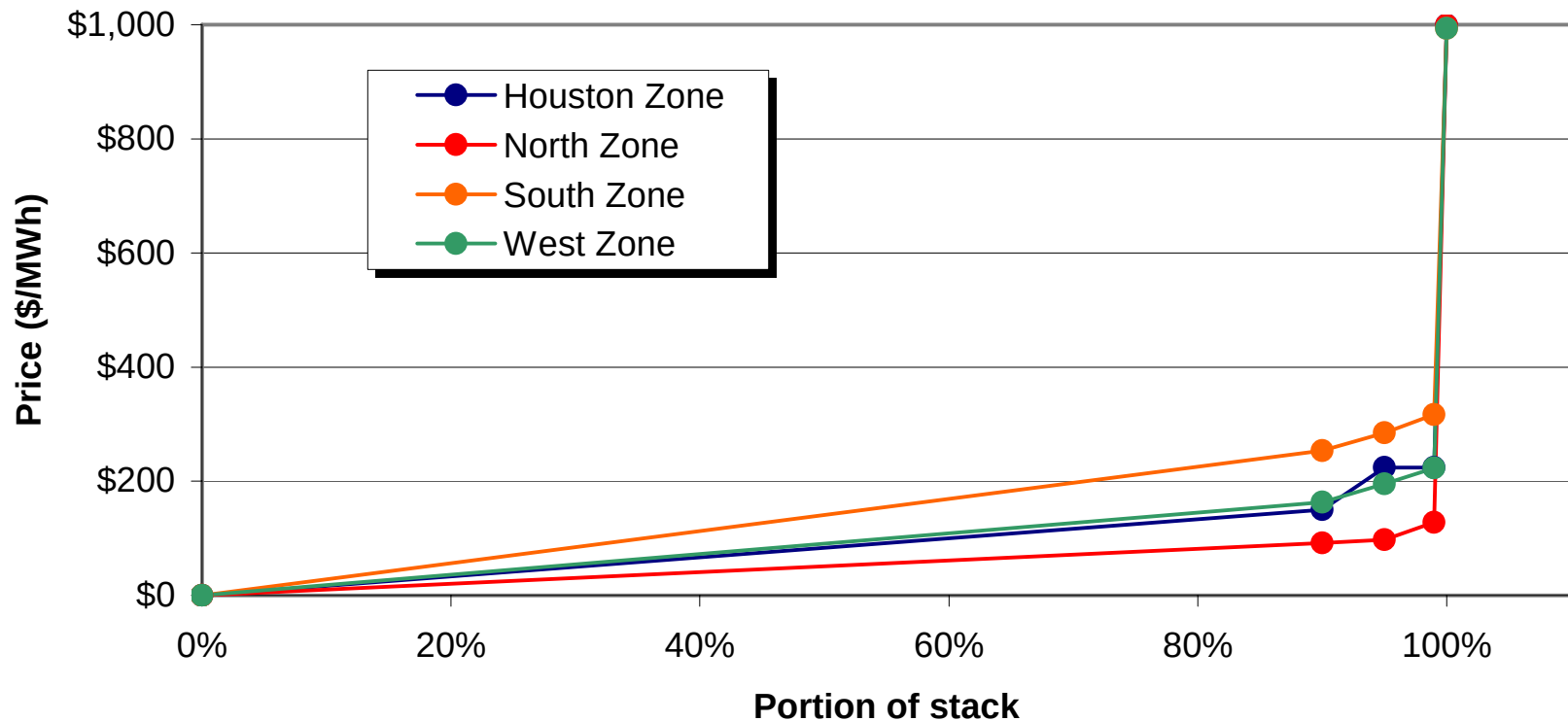


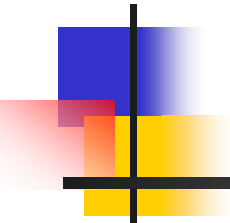
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Retrospective Impact Analysis of Hockey Stick Mitigation in Texas

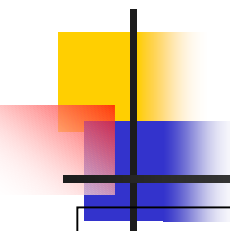
July 1, 2002 through March 31, 2003

**Bid Curves above \$900:
Average 90%, 95% 99% and 100% Points**





ANCILLARY SERVICES

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Ancillary Services

- Automatic Generation Control (AGC)
- Reserves with varying different response time
 - Spinning Reserves
 - Non-spinning Reserves
 - Replacement Reserves
- Voltage Support
- Black Start Capability



Procurement Auction Features

- Key feature - downward substitutability
- Basic Approaches:
 - Sequential auctions (substitution through rebidding)
 - Auction order: Regulation, Spin, Nonspin, Replacement
 - Offer prices: Single, Simultaneous multiple, Sequential
 - Uniform market clearing price in each auction
 - Simultaneous auctions (substitution by ISO)
 - Objective function: Min social cost or Min procurement cost
 - Settlement rules: MCP based on offer type, MCP based on use, Marginal value, Pay as Bid.
 - Pricing to buyers: Marginal cost, MCP based on type

Example

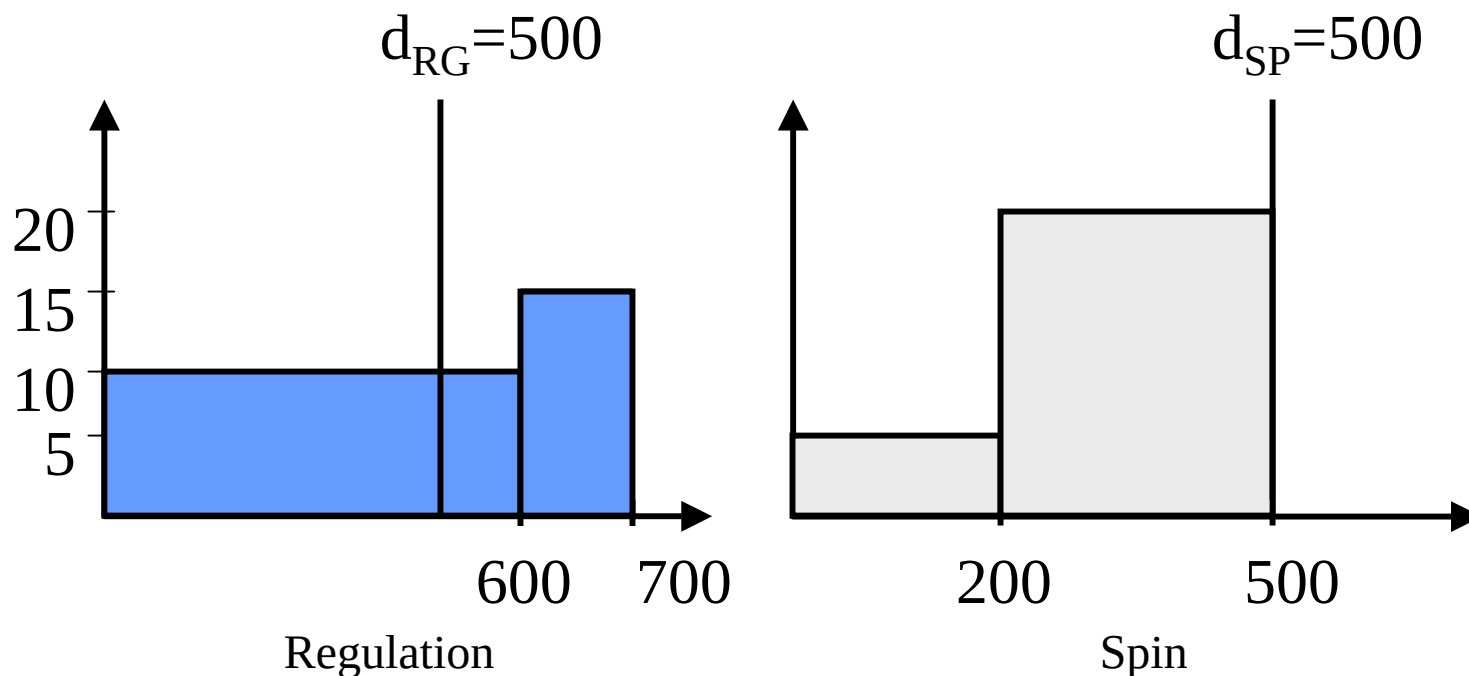
■ Two type example

Regulation 600 MW at \$10 /MW

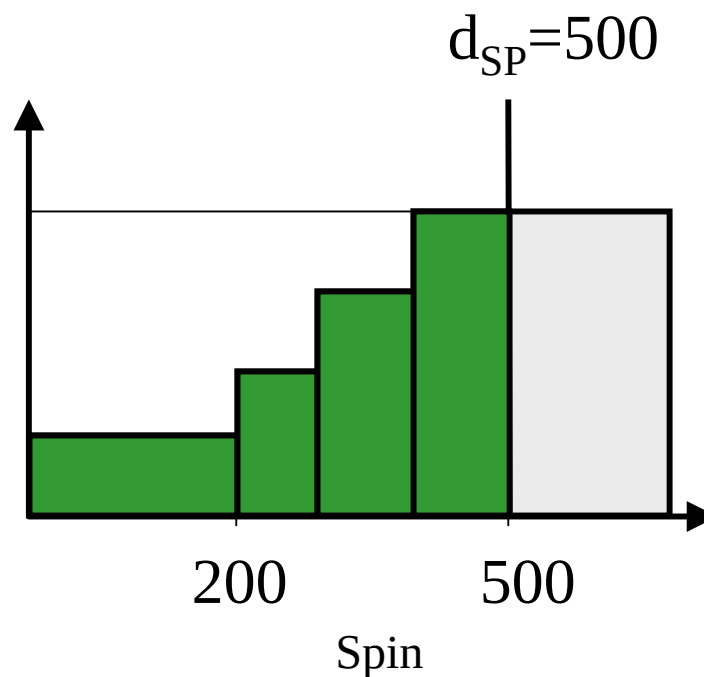
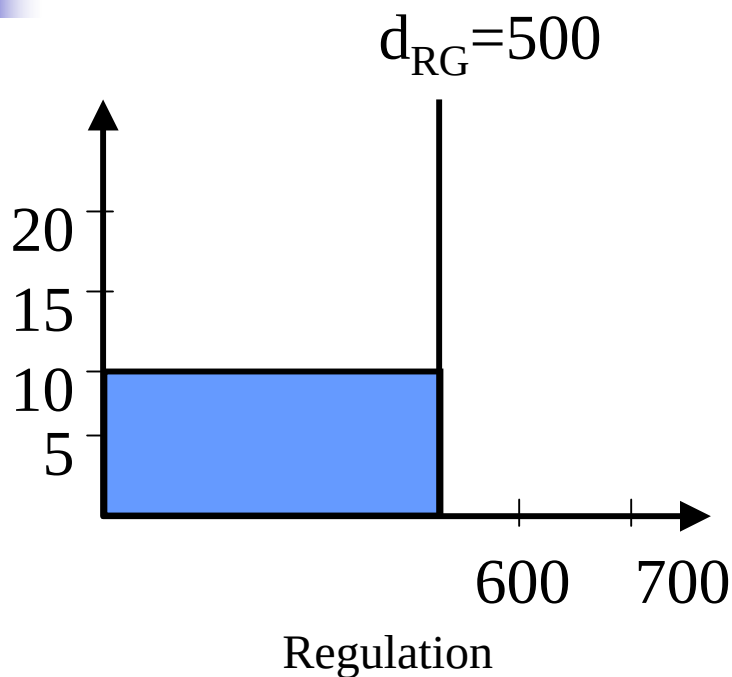
100 MW at \$15 /MW

Spin 200 MW at \$ 5 /MW

300 MW at \$20 /MW



Sequential Auction

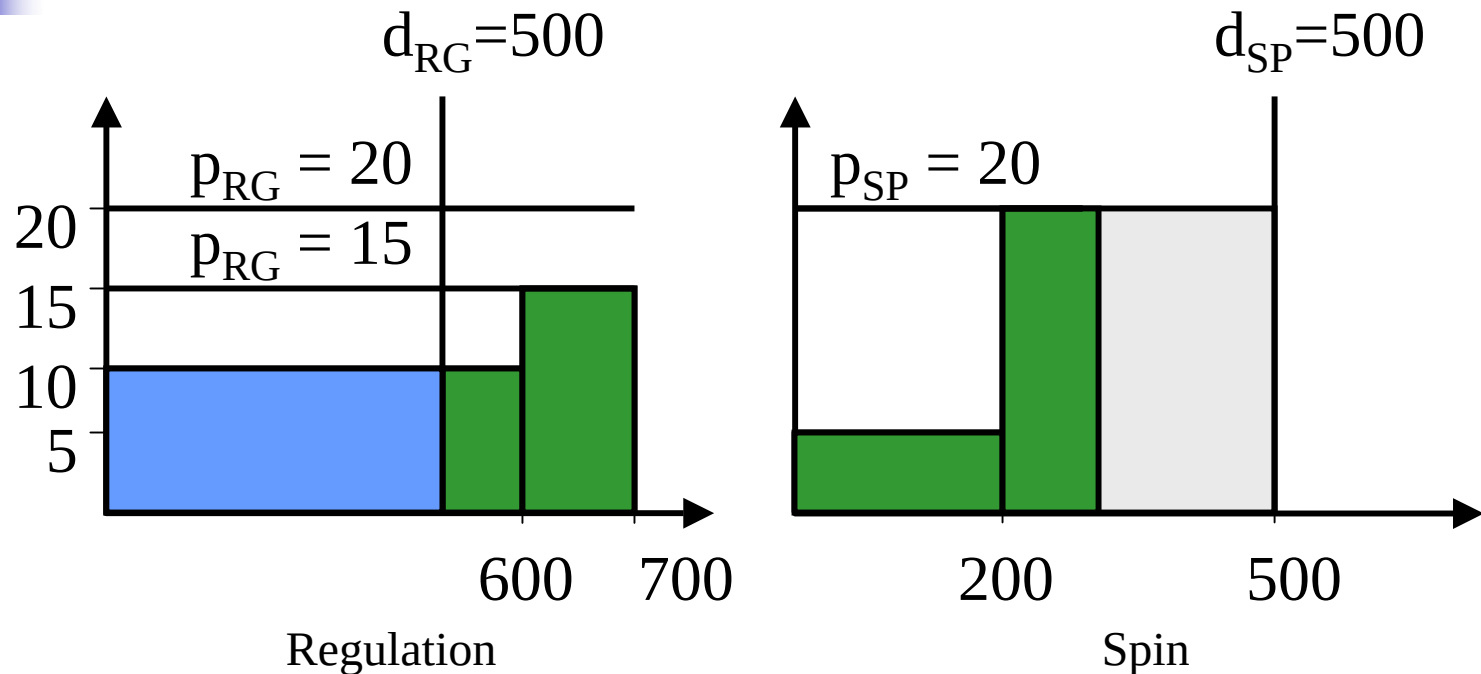


$$\begin{aligned} \text{Total Procurement Cost} &= 500 \cdot 10 + 500 \cdot 20 \\ &= \$15,000 \end{aligned}$$

$$\text{Revealed Social Cost} = \$10,500$$

Simultaneous Auction

Minimum Social Cost Selection



Settlement Rule

Procurement Cost (\$)

Highest Accepted Bid 16,500

Misrepresent quality

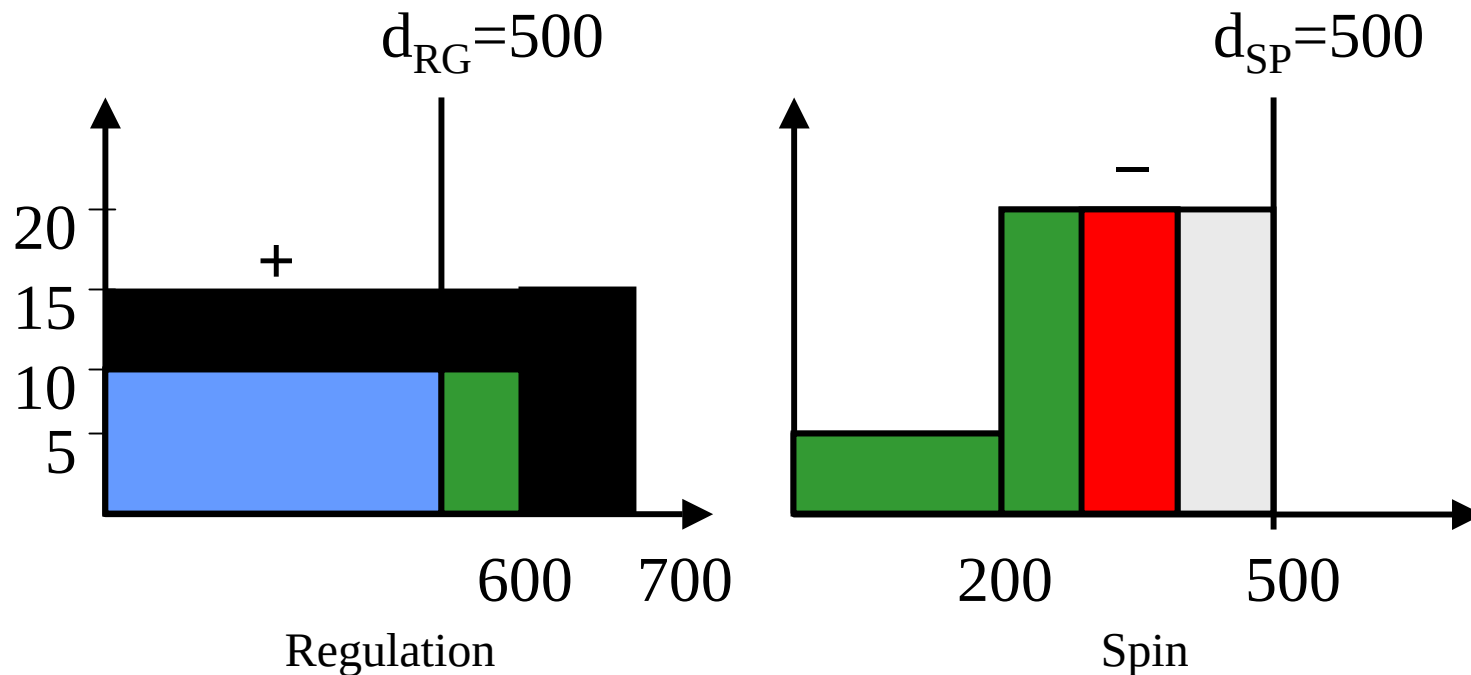
Marginal Value 20,000

Incentive compatible

Pay as Bid

10,500 (Soc. Cost) Misrepresent cost

Rational Buyer Auctions (Min procurement cost)



Saves (black): 4500

Spends (red): 2000

Difference: 2500

Price Reversals in New England Under Sequential Auction



1.1. Operating Reserves Market Flaws: TMSR, TMNSR, TMOR.

During June and July the ISO identified design flaws in the operating reserve markets of Ten Minute Spinning Reserve (TMSR), Ten Minute Non-Spinning Reserve (TMNSR), and Thirty Minute Operating Reserve (TMOR). The operating reserve design flaws resulted in markets that are not workably competitive. In a competitive market, higher quality goods should command higher prices. In the operating reserves markets prices did not appear to be reflective of costs and lesser quality reserves received higher prices. For example, Thirty Minute Operating Reserve ("TMOR") is less useful than Ten Minute Non-Spinning Reserve ("TMNSR"), Ten Minute Spinning Reserve ("TMSR"), or Energy. However, at times, TMOR prices exceeded the prices for all three of the other products.

[From ISO New England Monthly Market Report, June 1999]

Price Reversals in California Under Rational Buyer Procurement



- Price reversals have been reported in the CAISO ancillary service market under the rational buyer auction
- On March 20, 2000 in HE 19, there was a spike in the Replacement Reserve price. The following are published prices for NP15:

Reg-Up: $P1 = 18.44 \text{ \$/MW}$

Spin: $P2 = 35.97 \text{ \$/MW}$

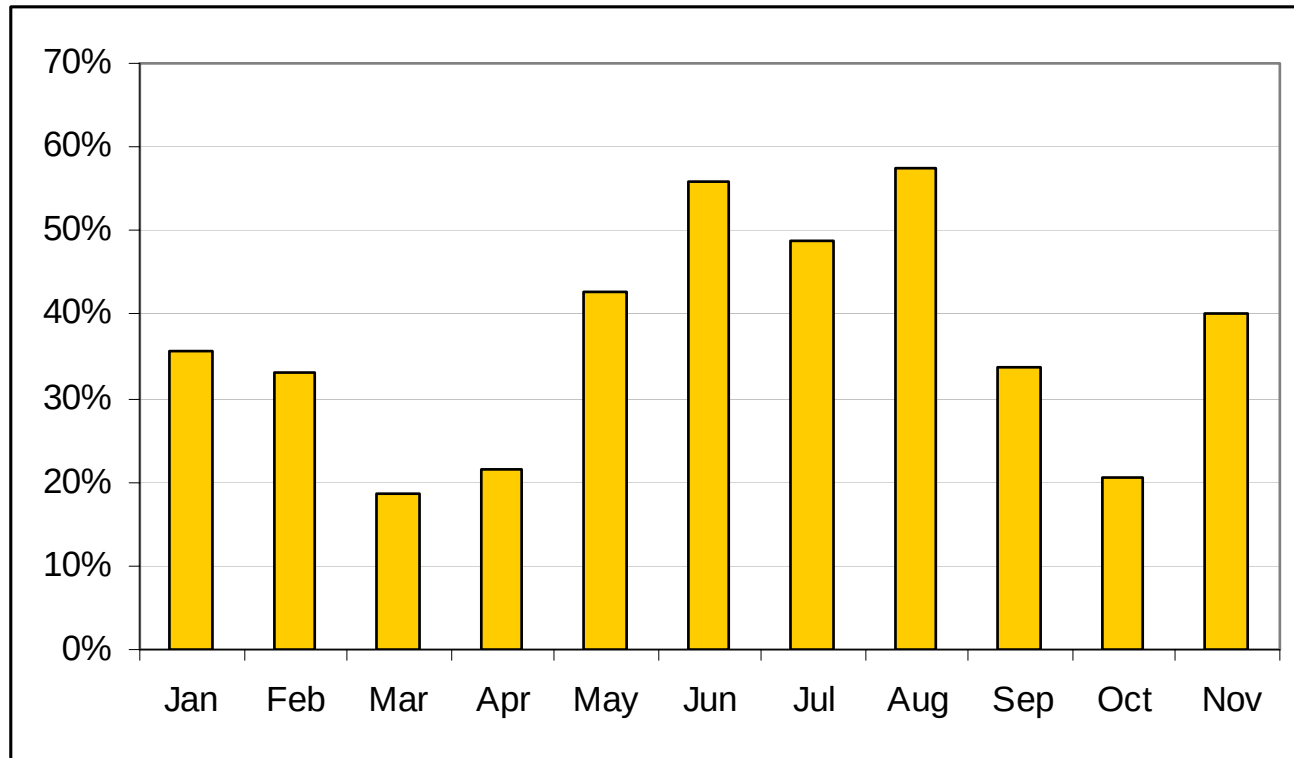
Non-Spin: $P3 = 18.00 \text{ \$/MW}$

Replacement: $P4 = 198.98 \text{ \$/MW}$

Note that $P4 > P3, P2, P1$. Also $P2 > P1$.

- A similar pattern in AS prices was observed on Feb 29, 2000 in HE18 when replacement reserve prices were 122\$/MW

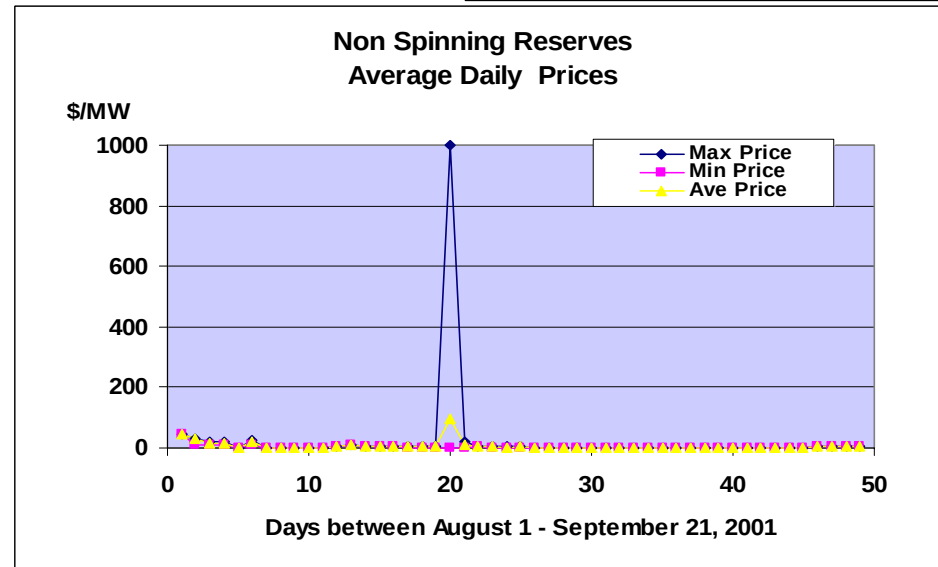
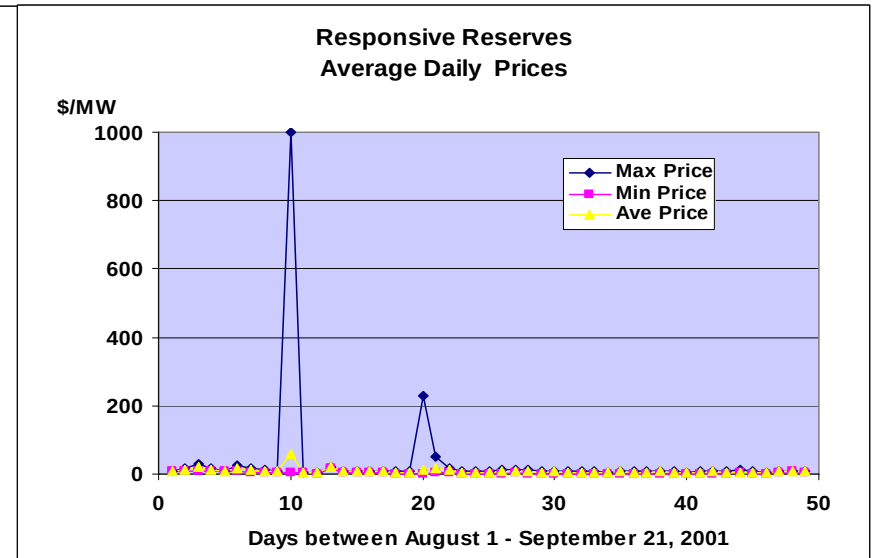
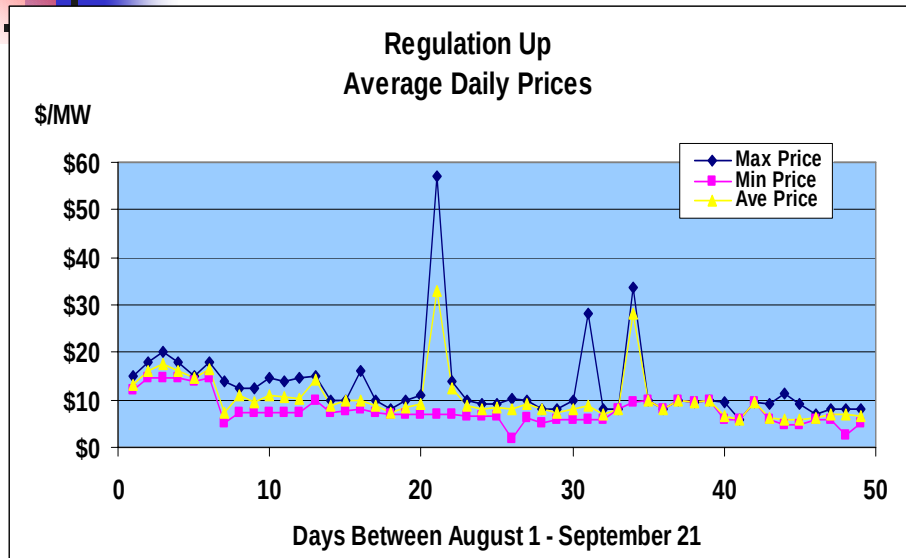
NP15 A/S Price Reversal Frequency in 2000

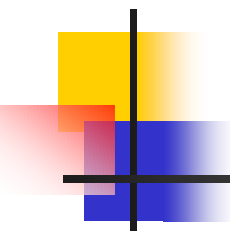


If Reg = 4, Spin = 3, Non-spin = 2, Repl. Res = 1,
a price reversal occurs if $\text{Price}_i > \text{Price}_j$ for $i < j$ where i, j denote the type of A/S

Price Reversals in ERCOT AS Markets

Under Sequential Auction



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Conclusions

- If gaming is possible it will happen
- Market design must be proactive in anticipating perverse incentives and gaming opportunities
- Structural solutions and incentive mechanisms are preferred but not always possible
- Ex- post market power mitigation too cumbersome and ineffective
- On line ex-ante intervention is needed to mitigate market failure and regulate behavior but distortions should be minimized.